



J. E. Stallmeyer

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Help find the oldest steel railway bridge and win a cash prize—see page 1.



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CSX bridge in Baltimore, Maryland at Bayview junction still safely carries heavy traffic despite its 107 years of use.

Help Find Our Oldest Steel Bridge — \$200 Prize in Each of Two Categories —

In the October 1991 bulletin, the cover article introduced us to the oldest railway bridge in North America—an 1829 stone arch on CSX. Following the article, AREA headquarters was asked what the oldest steel bridge was. Since no answer to this appeared to be available, a contest is being held to find the oldest operational steel railway bridge in North America.

To start off the search, we offer the candidate above and on the front cover, a 107-year old truss bridge carrying a heavily used industrial branch of CSX in Baltimore, Maryland, a neighbor of the 1829 bridge. This truss bridge was built in 1885 to carry the then-new main line of the Baltimore and Ohio to Philadelphia. This main line involved a ferry operation across Baltimore Harbor, which was replaced by a new line through Baltimore in 1895 that tunneled under the city and involved the first non-transit use of electric locomotives on a U.S. railway. This new line through Baltimore then left the portion of the line on which the 1885 bridge is located as a branch serving some large industries. The bridge crosses over Amtrak's Northeast corridor, which carries heavy passenger traffic as well as Conrail freight trains and MARC commuter trains (see photo on next page). While the original truss has not been strengthened since it was built, a new system of floor beams and stringers was installed for a single track operation instead of the former double track (see photo on top of next page).

The rules for the contest to find the oldest steel railway bridge are as follows:

1. For the contest, there will be two \$200.00 prizes, one in each category.
2. The first category will be any steel (or other form of iron) bridge over 30' in span and the second, truss bridges over 60' in span.
3. The arch, girder, or truss must not be substantially altered or strengthened since its original construction, unless the age of the alteration or strengthening itself is old enough to be a candidate for oldest structure.



The photo above shows detail of the 1885 bridge, including the rebuilt floor system to carry single track instead of the original double track.

4. The structure must be presently in railroad service, not simply remaining in existence or used for highway use instead of railroads, and must not be in use solely for museum or tourist railway operation.
5. The structure must be in the location in which it was originally used, unless the age of the relocation itself is old enough to be a candidate for the oldest structure.
6. Entries must be submitted to AREA headquarters by June 1, 1992.

Bridge safely carries heavy freight trains over Amtrak's Northeast corridor, which is also used by Conrail freights and MARC commuter trains, as shown below.



Excerpts From Annual Report of A.R.E.A. Committee 1 - Roadway and Ballast

W. L. Heide, Chairman

Brief status of each Subcommittee Assignment:

Subcommittee A — Recommendations for Further Study and Research

No recommendations from this subcommittee, however further study will be referred to in the appropriate subcommittees. Continue this subcommittee.

Subcommittee B — Revision of Manual

Reported that an adequate number of assignments were being investigated. In some instances existing Manual material might be re-dated without change.

Subcommittee 1 — Roadbed

Assignment D1-1-86, report on criteria justifying the use of undercutters, was decided to be dropped previously because of the report being of lesser value and not approved for publication.

Assignment D1-2-86 is to update the Manual sections on construction of roadbeds including sections 1.1, 1.3 and 1.4. Assignment in progress and a 1992 completion date is expected.

Subcommittee 2 — Ballast

Assignment C2-1-86 provides recommendations regarding the AAR ballast research program and other such programs. This is a continuing assignment and at present is monitoring the operation of the FAST/HAL ballast and subgrade tests.

Assignment D2-1-88 deals with tamping procedures and their relation to the ballast. Planning continues with field work scheduled to begin in the Spring of 1992. Gathering and reduction of data is expected to take two years, therefore a report date of 1994 is planned.

Assignment D2-2-89 on the study and report of performance characteristics of hot plant mixed asphalt courses in the track substructure is continuing with emphasis at this time on the economics. Report is at least 2 years away.

Assignment D2-3-89 deals with comparing in-track performance of ballast with laboratory results obtained by the Mill Abrasion Test. Emphasis is on the possible use of the Mill Abrasion Test as a recommended test. Laboratory testing is getting underway at 7 laboratories and it is expected that the testing and reduction of data will take 18 months.

Assignment D2-4-89 of the study on in-track weathering of ballast materials and degradation of ballast particles by weather and chemical actions has been completed and published.

Subcommittee 3 — Natural Waterways

The assignment D3-3-89 to develop a glossary, has been completed, and a letter ballot has been approved to have the glossary added to the Manual. No further assignments have been suggested for this subcommittee and it is recommended that the subcommittee members be reassigned at this time.

Subcommittee 4 — Culverts

Assignment D4-1-88 has been partially completed with respect to jacking culvert pipe. A letter ballot has been approved for this portion of the assignment. The assignment will be modified to indicate the remaining assignment of installation of culvert pipe and completion is expected by the end of 1992.

Assignment D4-2-89 on methods of installing culverts inside existing culverts has been completed and a letter ballot has been approved for the Manual revision titled "Culvert Rehabilitation."

A new assignment is being recommended to look at procedures for culvert inspection.

Subcommittee 5 — Pipelines

Assignment D5-2-81 on the use of plastic carrier pipes is well underway and a draft report is expected by Spring, 1992.

Assignment D5-3-91 to develop specifications for uncased high pressure gas pipelines within the railway right of way is just beginning and will continue through 1992.

Subcommittee 6 — Fences

Assignment D6-1-87, dealing with security fencing is going rather slow at this time and could use some expertise.

Assignment D6-2-87 concerning the review and updating recommendations for snow fencing is underway and a draft is expected by Spring of 1992.

Subcommittee 7 — Signs

An assignment to review the Manual material and make revisions as necessary is being progressed. Results are expected by Fall, 1992.

Subcommittee 8 — Tunnels

Assignment D8-1-87 to review and update manual recommendations for tunnels and D8-2-87 to report on the Rogers Pass Project on the Canadian Pacific are both moving slowly and expected date for completion is in 1993.

Subcommittee 9 — Vegetation Control

Assignment D9-2-89 to review and update Manual text recommendations for vegetation control has a draft expected by the Fall of 1992. A paper entitled "Comparing the Long Term Effects of Chemical and Mechanical Brush Control" was approved for publication in the bulletin.

Subcommittee 10 — Geosynthetics

Assignment D10-3-88 has progressed to the stage of a report on the use of geosynthetics in retaining walls and slope stabilization. Approval for publication in the bulletin is expected by Spring, 1992.

Assignment D10-1-89, geosynthetics for stabilization of track roadbed is being progressed and a draft is expected by Fall, 1992.

An Abrasion Test for geotextiles is now available as ASTM D-4886 and the original assignment to develop table 10.1.2.2 for Abrasion Resistance is in the process of being completed.

Excerpts From Annual Report of A.R.E.A. Committee 2 - Track Measuring Systems

R. F. Silbaugh, Chairman

Status of Subcommittee Assignments**Subcommittee A — Recommendations for further study and research.**

It is recommended that the following new assignments be made:

- D1-1-92 Techniques that may be used to measure various track geometry parameters. Describe the current technology available for making these measurements.
- D1-2-92 How to identify and locate priority defects detected by geometry cars in the field. Describe what a defect looks like on a chart or report and then how to find it in the field.
- C2-1-92 Interface with organizations dealing with rail flaw detection and inform the membership. (This combines existing assignments C-2-1-86 and C-2-2-86)

D2-1-92 Develop recommended practice for measuring rail parameters for use in planning rail grinding, transposition and renewal.

D3-1-92 Gage strength measurement.

D3-2-92 Measurement systems related to track lateral stability.

Subcommittee B — Revision of Manual

The following article was published in AREA Bulletin No. 729 (December 1990):

— Recommendations for Establishing and Maintaining a Track Geometry Data Base.

The following articles have been submitted and are due for publication in January 1992 AREA bulletin.

— Compilation of Various Track Geometry Parameters and Related Elements used when describing Track Geometry.

— Description of a Generic Track Geometry Measuring Vehicle.

— Recommended minimum performance guideline for rail testing.

Subcommittee 1 — Track Geometry

C1-1-85. Proposed recommended practice for geometry cars.

Assigned: March 1, 1985

Estimated Completion: November 1, 1991

The articles listed under Subcommittee B (Revision of Manual) have been published or are due for publication in AREA bulletins which brings this assignment to a conclusion.

C1-1-85. Survey data processing techniques and equipment used on different railways' track geometry vehicles.

Assigned: March 1, 1985

Estimated Completion: November 1, 1991

This survey is completed and expect to have data tabulated by November 1991 and submitted for publication in the AREA bulletin. Due to the constant change in technology, this type of data must be updated periodically.

Subcommittee 2 — Rail Measurement Systems

D2-1-85. Investigate the characteristics of corrugation prevalent on North American Railways to establish specifications for their measurements by automated means.

Assigned: March 1, 1985

Estimated Completion: November 1, 1991

The results of a survey of North American Railway's use of corrugation measurement devices was published in the AREA Bulletin. The subcommittee found that there is not yet enough data on measuring devices to develop a specification for inclusion in the manual. Therefore, it is recommended that this assignment be dropped.

D2-1-86. Develop a recommended practice describing minimum acceptable flaw detection system capabilities in terms of flaw types and sizes.

Assigned: June 1, 1986

Estimated Completion: November 1, 1991

A recommended Performance Guideline for Rail Testing has been developed to define minimum acceptable performance reliability in terms of the percentage of rail flaws of different sizes that must be

correctly located by a rail flaw detector car. The committee voted to submit it to the Board for inclusion in the AREA Manual.

D2-2-86. Develop a recommended practice describing test rail specimen which includes simulated defects of known size and orientation to demonstrate minimum rail flaw detection system capabilities.

Assigned: June 1, 1986

Estimated Completion: November 1, 1991

Not enough information available at this time. The results of a literature search and contacts with manufacturers indicates a lack of information in this area. It is recommended this study be canceled until additional research and information is available.

C2-1-86. Interface with organizations dealing with the development of rail flaw detection technologies.

C2-2-86. Inform the membership of the state-of-the-art in rail flaw detection.

Interfaces are in place and it is recommended that these two assignments be combined into a more general new assignment **C2-1-92**, Interface with organizations dealing with rail flaw detection and inform the membership.

Subcommittee 3 — Track Structure Assessment

C3-1-85. Evaluate the need and potential use by railways of information on track modules, subgrade moisture and lateral tie strength, each of which can be evaluated with current technology.

Assigned: March 1, 1985

Estimated Completion: November 1, 1985

This assignment is too broad. It is recommended that it be replaced with the following two assignments:

D3-1-92. Gage Strength Measurement

D3-2-92. Measurement Systems Related to Track Lateral Stability.

Excerpts From Annual Report of A.R.E.A. Committee 3 - Ties and Wood Preservation

J. L. Watt, Chairman

Report on Special (D) and Continuing (C) Assignments

Assigned Number	C1-2-63	C1-1-62	D1-1-89	C2-1-63	C2-2-63	C2-3-63
Description of Assignment	Tie Specs	Tie Design Spacing	Wood Tie Disposal	Preservative Specs/Research	Seasoning Trtmt. Specs	Care/Handling Cross & Switch
Date Assigned/(Undertaken)	1963	1962	1989	1963	1963	1963
Estimated % Completion	Continuing	Continuing	30%	Continuing	Continuing	Continuing
Estimated Completion Date	Continuing	→	1993	→	→	→
Problems	None	None	None	None	None	None
Recommend Assignment Being Dropped	No	No	No	No	No	No
Recommend Assignment Being Postponed	No	No	No	No	No	No

Assigned Number	C3-1-63	C3-2-63	C4-1-76	C4-3-63	C4-3-66	C4-4-82
Description of Assignment	Tie Renewal Stats	Service Test Records	Solid Sawm Substitute	Anti-Split Research	Iron Degradation	Liaison AAR-AREA
Date Assigned/(Undertaken)	1963	1963	1976	1963	1966	1982
Estimated % Completion	Continuing	Continuing	Continuing	80%	Continuing	Continuing
Estimated Completion Date	→	→	→	Continuing	1992	→
Problems	None	None	None	None	None	None
Recommend Assignment Being Dropped	No	No	No	No	No	No
Recommend Assignment Being Postponed	No	No	No	No	No	No

Excerpts From Annual Report of A.R.E.A. Committee 4 - Rail

H. W. Newell III, Chairman

Report on Special (D) and Continuing (C) Assignments

Assigned Number	C1-1-74	D1-1-81	D1-2-81	C2-1-55	D2-1-88	D2-2-88	C3-1-76	C4-1-73
Description of Assignment	Collaborate w/ Rail Welding, Grinding & Test. cont.	High Strength Rail Welding	Weld Qualif. Testing	Collaborate w/ Rail & Joint Bar Manufacturers	Web Cracking of Rail from Roller Straightening	Tolerance and Method of Meas. Rail Head Radius	Rail Statistics	Update Data on Methods & Equip. for Weld. Repairs
Date Assigned/ (Undertaken)	1974	1981 (or earlier)	1981	1955	1988	1988	1976	1973
Estimated % Completion	Continuing	75%	100%	Continuing	95%	50%	Continuing	Continuing
Estimated Completion Date	N.A.	1993	1991	N.A.	1992	After 1992	Annual	N.A.
Problems	NIL	Redrafting	NIL	NIL	Report to be written	Included in gages	NIL	NIL
Recommend Assignment Being Dropped	No	No	Yes	No	No	No	No	No
Recommend Assignment Being Postponed	No	No	No	No	No	Yes (till after D5-2-88 completes its work)	No	No

A.R.E.A. Committee 4 - Rail (cont.)

Assigned Number	C5-1-78	D5-2-88	C5-1-78	C6-1-62	C6-1-62	C6-1-62*	C7-1-68	C8-1-88
Description of Assignment	Rail Specs. Research & Development	Wheel/Rail Profiles	Standard Mill Check Gauges for Rail	Joint Bars: Specifications, Testing	Specifications for Bonded Ins. Rail Joints	Complete Review & Redraft of Splice Bar Standards & Drawings	Effect of Heavy Wheel Loads on Rail	Management of Rail Test Resources
Date Assigned/ (Undertaken)	1978	1988	1989	1962	1985	1987	1968	1988
Estimated % Completion	Continuing	50%	75%	Continuing	85%	99%	Continuing	100% Complete
Estimated Completion Date	N.A.	1992 +	1992	N.A.	1992	1991	N.A.	1991
Problems	NIL	Very complex subj. Optimum head contour, function of track curvature	NIL	NIL	Slight Redraft	Minor	Very wide stat. scatter in results from HAL FAST tests	Waiting for response from recent proposal
Recommend Assignment	No	No	No	No	No	Yes	No	Yes
Being Dropped								
Recommend Assignment	No	No	No	No	No	No	No	No
Being Postponed								

Excerpts From Annual Report of A.R.E.A. Committee 5 - Track

J. D. Baker, Chairman

Report on Special (D) and Continuing (C) Assignments

Assigned Number	B-1-89	C2-1-79	D4-1-84	C5-1-90	D5-4-81
Description of Assignments	Swt. Pt. Chg. Out	Track Tools	Rail Fast Wood Ties	Update Trk. Trkwork Pl.	Explosive Hard. Cast.
Assigned Date	12/89	2/79	4/86	12/90	1/81
Estimated Comp. percent (%)	0%	Continue	95%	Continue	95%
Est. Compl. Date	10/92	Continue	5/91	Continue	10/91
Problems	None	None	None	None	None
Recommend Assignment Being Dropped/(Discontinued)	No	No	No	No	No
Recommend Assignment Being Postponed	No	No	No	No	No
Comments			AREA Appro & Test		Closed out?

Assigned Number	D5-8-89	D5-2-91	D8-2-84	D8-3-85	D8-4-89
Description of Assignments	TTC TO. Design	Fastn. for Frog & Cast	Supr. Elev. & Sprl. Lg.	TO. Geom. & Inc. Spd.	Vert. Cvr. Rate/Chg.
Assigned Date	5/89	3/91	10/89	10/89	10/89
Estimated Comp. percent (%)	0%	0%	10%	10%	0%
Est. Compl. Date	10/92	12/93	5/92	5/92	5/93
Problems	None	None	None	None	None
Recommend Assignment Being Dropped/(Discontinued)	No	No	No	No	No
Recommend Assignment Being Postponed	No	No	No	No	No
Comments	AAR/TTC Evaluate	Sec. Lock Evaluate			

Excerpts From Annual Report of A.R.E.A. Committee 6 - Buildings and Support Facilities

B. R. Schwab, Chairman

Subcommittee Assignments:

Subcommittee A — Recommendations for Further Study and Research

Investigating new topics for Bulletin information

Subcommittee B — Revision of Manual

Progress being made.

Subcommittee D-1-80 — Design Criteria for C.T.C. Dispatch Facilities

Report published in Manual.

Subcommittee C-1-73 — Design Criteria for Car Shops

Report completed and sent to membership for Committee approval. Estimated completion date 1992.

Subcommittee C-3-84 — Design Criteria for Railway Office Buildings.

Report published in Manual.

Subcommittee D-3-87 — Design Criteria for Wheel and Bearing Shops.

Report is actively under review by subcommittee. Estimated completion date 1992.

Subcommittee D-5-89 — Design Criteria for Maintenance-of-Way Facilities.

Report is in final draft. Estimated completion date 1992-3.

Subcommittee D-4-89 — Design Criteria for Railway Material Management Facilities.

Report is actively being progressed by the subcommittee chairman. Estimated completion date 1992-3.

Excerpts From Annual Report of A.R.E.A. Committee 7 - Timber Structures

W. Benton III, Chairman

Subcommittee Status:

Subcommittee A — Recommendations for Further Study and Research.

Committee 7 is currently looking into "Stress Laminated Construction for railway loadings. We plan in the future to expand the section on timber maintenance and look into glue laminated construction.

Subcommittee B — Revision of Manual.

New Subcommittee chairman Mr. K. G. Hauschildt, Norfolk Southern.

Subcommittee B**C-1-53 — Specifications for Design of Wood Bridges and Trestles.**

Work continues on E-80 load charts, estimate completion in 1992.

C-2-90 — Timber Technology Applications

We are continuing to monitor what is going on in the timber industry looking for any new developments that may have application to the Railway Industry.

D-4-82 — Effect of Unit Trains on Timber Trestle Components

We continue to have trouble keeping a subcommittee chairman on this assignment. The committee feels it is an important topic, but it may have to reconsider if the work does not progress shortly.

D-5-89 — Methods of Upgrading Existing Timber Trestles

This subcommittee is doing very well. We are looking forward to making additions to the manual in this area by the end of 1992.

D-6-89 — Specifications for Timber Bridge Ties

The entire Committee is currently reviewing the Subcommittee's work. It is expected to be completed by the end of 1992.

Excerpts From Annual Report of A.R.E.A. Committee 8 - Concrete Structures and Foundations

G. W. Cooke, Chairman

Subcommittee Activities:**Subcommittee A. Recommendations for Further Study and Research**

We are participating in the AAR, NSF, and University of Illinois Research Program where they are investigating Dynamic Impact on Railroad Structures. The preliminary results of the field work indicate that the test equipment is working properly and should give us good information for our use.

Subcommittee B. Revision of the Manual

This committee reviews all Manual material in order to verify that it is in keeping with the standard AREA format. The format for the commentary is under review, and the first commentary has been issued for printing in the Manual.

Subcommittee 1. Design of Concrete Structures**D1-1-84. Develop Specifications for Precast and Cast-In-Place Concrete Segmental Bridges**

This assignment should be going out for Letter Ballot in 1992. The Commentary will follow with a separate ballot. This material is new to the Manual and has involved extensive research.

D1-1-90 Concrete Slab Track: Formulate a recommended practice for the design and construction of concrete slab track with a direct fixation guideway for the rail, collaborating with Committee 5.

This assignment is now underway with the specification started within the subcommittee.

D1-5-87. Investigate Applicable Impact Factors

This assignment is suspended at the moment awaiting the results of the AAR Bridge Testing which is underway.

D1-8-88. Review and Rewrite Part 2 as Necessary

This assignment is complete with the issuance of Manual Material.

D1-9-88. Review and Rewrite Part 17 as Necessary

This assignment is underway with the specification review started within the subcommittee. Completion of this assignment is expected in 1992.

Subcommittee 2. Foundation and Earth Pressures**C2-2-90. Design of Proprietary Walls: Monitor Committee 1's Assignment D1-3-88 and provide a specification for design when and if necessary.**

This assignment is underway with the consideration of developing a new Part in the Manual.

D2-1-89. Review and rewrite Part 20 as necessary

This assignment material has passed the subcommittee and is ready for Letter Ballot of the general committee.

D2-2-89. Commentary for Part 20 on flexible sheet pile bulkheads.

This assignment has just been undertaken now that a format for the commentary has been developed.

D2-2-90. Temporary Protection for Construction: Develop a specification for the design and execution of temporary shoring of the track structure.

This assignment is underway and represents new material for the Manual. Due to the nature of the material being produced, extensive research has been necessary.

Subcommittee 3. Durability of Concrete**C3-1-88.** Monitor current waterproofing practices

This assignment is a continuing assignment, and no material has come out of the subcommittee this year.

C3-1-90. Prepare commentary for Part 1

This assignment is continuing and Manual Material has been approved and submitted for publication.

D3-1-88. Investigate and report on current methods of protecting concrete

This assignment is complete with Manual Material being approved and submitted for publication.

D3-1-89. Guidelines for field bending of partially embedded reinforcing bars

This assignment is complete with Manual Material having been approved and submitted for publication. Field bending of grade 60 bars should be undertaken with care.

D3-1-90. Prepare section in Part 1 on use of fly ash.

This assignment is complete and the approved material has been submitted for publication as Manual Material.

C3-2-89. Review and rewrite Part 1 as necessary.

This assignment is within the subcommittee who reports progress. Some portions of this assignment have been performed under other topics and submitted for publication.

D3-2-90. Prepare article on concrete durability.

This assignment is well underway and is being typed for Letter Ballot.

D3-3-90. Prepare article on alkaline reaction.

This assignment is under study within the subcommittee which reports progress toward completion.

D3-4-90. Review specifications available on fiber reinforcement for possible development as Manual Material.

This assignment has just begun, and data collection is underway.

Subcommittee 4. Repair, Restoration and Strengthening of Concrete Structures**D4-2-87.** Study AAR bridge program and make recommendations for implementation at FAST.

This assignment has been recommended to be dropped since there has been no activity at FAST within the 4 year period since the assignment was undertaken, and there is no indication that such work is contemplated.

D4-3-88. Develop specifications for inspection, evaluation, and repair of damaged prestressed concrete.

This assignment is complete with approved Manual Material having been submitted for publication.

D4-4-88. Develop criteria for prevention of scour damage to bridge piers.

The assignment is well underway and subcommittee reports progress toward the goal of Manual Material.

D4-1-91. Develop a commentary for Part 14

The assignment has just gotten underway, now that a format for the commentary is available. The subcommittee reports initial progress.

Subcommittee 5. Design of Concrete Components for Bridges in Seismic Zones

D5-1-89. Develop design criteria or retrofit specifications or guidelines.

The subcommittee is awaiting the development of the needed steps to take when the ad-hoc AREA seismic committee submits the necessary guidelines. A new subcommittee chairman will be assigned when the proper direction is established.

Subcommittee 6. Design of Foundations

D6-1-90. Review and revise Part 12 on concrete poles.

This assignment is complete having submitted approved material for the Manual.

D6-2-89. Review and rewrite Part 22 as necessary.

This assignment is complete having submitted approved material for the Manual.

D6-3-89. Commentary for Part 4 on pile foundations

This assignment is well underway, and the subcommittee reports progress toward completion now that the format has been established. This specification may need to extend into 1993.

Excerpts From Annual Report of A.R.E.A. Committee 9 - Highway-Railway Crossings

K. J. Anderson, Chairman

Status of Subcommittee Assignments:

Subcommittee A—Recommendations for Further Study and Research.

This subcommittee is responsible for the development of new topics which should be addressed in the manual. In our summer meeting, the chairman conducted a brain storming session to develop additional topics of interest for the committee. The brain-stormed topics, as well as the possible subcommittee assignment, was furnished to each subcommittee for their further consideration.

Subcommittee B—Revision of Manual.

This subcommittee is responsible for the processing of manual revisions through the committee.

Although no manual revisions were proposed this year, it is hopeful that manual revisions will be recommended by Subcommittees D-1-87 and D-4-90 next year.

Subcommittee D-1-87—Foundations for Highway-Railway Grade Crossings, collaborating with Committee 1.

The chairman has contacted Committee 1 concerning the use of asphalt underlayment. Committee 1 has a subcommittee assigned to this topic and is involved in developing specifications for inclusion in Chapter 1. Subcommittee D-1-87 has been invited to attend their next committee meeting. Once developed, Chapter 9 will cross-reference Chapter 1's specifications. This subcommittee is also reviewing cross-section diagrams for drain pipes and fabric for possible inclusion in the manual.

Subcommittee C-1-87—Grade Crossing Surfaces

This subcommittee has been reviewing various reports in an attempt to come up with some guidelines for using certain types of crossing surface materials. They are also collecting cross-section diagrams from various Railroads showing drains, fabric, and asphalt at crossings. This subcommittee is also reviewing Penn State's report on hold down devices.

This subcommittee is collecting data from the AAR regarding locations for joints in relation to the end of the crossing. They are also developing a survey to send to State highway departments as well as the Railroads to collect data as to their respective experiences with various types of crossing surfaces.

Subcommittee D-2-87—Approaches to Highway-Railway Grade Crossings.

This subcommittee has been monitoring research conducted by Dr. Ron Eck and West Virginia University's Civil Engineering Department relative to required approach grades for low clearance-long wheel base vehicles. They are currently reviewing Chapter 9's roadway profile recommendations in light of Dr. Eck's research. They hope to develop recommendations for our March meeting.

Subcommittee D-3-87—Grade crossing and separation elimination.

The chairman is finalizing a report based on the findings of the Ernst & Whinney report on grade separation elimination. Initially, he thought the subcommittee could be dissolved upon completion of this report; however, with the new FRA emphasis placed on crossing closures, it is felt that this subcommittee should remain intact to report on crossing closures activities.

Subcommittee D-4-90—Clearances for Highway Structures over Railroads.

The subcommittee has developed proposed language to be included in the manual. This material has been furnished to the committee for review. It is very likely that a manual revision will be developed for inclusion in 1992.

Excerpts From Annual Report of A.R.E.A. Committee 10 - Concrete Ties

A. N. Hanna, Chairman

Subcommittee Activities

Subcommittee A. Recommendations for further study and research.

As proposed in last year's report, the committee recommends that a research study be initiated to evaluate the durability of concrete ties currently in use by different railroads. This study should include both laboratory and field testing to examine the materials used in tie manufacture and relate material properties and manufacturing aspects to performance and durability. This information will help Subcommittee 4, Durability, identify the requirements that will insure durability and long service life.

Subcommittee B. Revision of Manual.

Subcommittee has considered a text for Article 1.1.5.3, Effects of Mass on Track Stability, a revised version of Article 1.2, Material, and new article on concrete turnout ties. The proposed text for these articles is still under review and a consensus is expected to be reached by the end of 1991. The recommended changes will then be submitted for Board approval.

Subcommittee 1. Flexural Strength.

C1-1-87. Monitor developments in prestressed and reinforced concrete technology which may affect concrete tie requirements.

D1-2-89. Investigate impact resistance and design requirements for concrete ties.

D1-3-87. Evaluate acceptance criteria for repeated load test.

In view of the increased interest in 125 ton cars, the subcommittee recommended that axle load should be considered a factor in developing concrete tie strength requirements and be included in Task C1-1-87. In Task D1-3-87, the subcommittee is considering the need for establishing a no-cracking criteria for the repeated load test. Work on these tasks is in progress. Because of the importance of these activities to the development of acceptable concrete ties, it is recommended that these activities be continued during the next year and that subcommittee assignments be revised in the future as needed.

Subcommittee 2. Switch, Bridge and Crossing Ties.

D2-1-89. Investigate requirements for concrete switch ties, bridge ties, and grade crossing ties.

The subcommittee has defined a work scope that will initially address recommended practice for the design and manufacture of concrete turnouts and use of concrete ties in grade crossings. The subcommittee has prepared a draft article on the subject for review and comment by the members. It is anticipated that this article will be submitted for ballot following the next committee meeting. Because of the increased interest in the use of concrete turnouts, we recommend that these assignments be continued until the subcommittee develops appropriate recommendations for incorporation in the Manual.

Subcommittee 3. Fastenings.

D3-1-83. Revise current test requirements.

D3-2-83. Investigate the effect of axle loads and tie spacing on fastening requirements.

D3-3-86. Review and recommend revisions of the load magnitude specified for the fastening repeated-load test.

Tasks D3-1-83 and D3-2-83 involve consideration of many variables and alternatives, and will require a considerable effort to complete these tasks. In Task D3-3-86, the subcommittee has recommended a simplification of the testing requirements for the Fastening Repeated Load Test by specifying the upward test load. In view of the need to develop better guidelines for rail fasteners, we recommend that this subcommittee assignments be continued until appropriate simplified recommendations are developed to replace the current Manual recommendations.

Subcommittee 4. Durability.

D4-1-89. Resistance of concrete ties to alkali aggregate reaction.

D4-2-89. Resistance of concrete ties to freezing and thawing.

D4-3-89. Resistance of concrete ties to rail seat abrasion.

The subcommittee has prepared a draft addressing Tasks D4-1-89 and D4-2-89 for review. However, as this subject is highly specialized and controversial, the subcommittee was unable to reach a consensus on an article for comment by the committee. Also, it seems desirable to seek review of the proposed articles by other than committee members. Subcommittee chairman and vice chairman will

review this need, develop a reviewer's list and seek AREA approval. Subcommittee chairman is providing information related to Task D4-3-89 through his involvement in an ad hoc committee on the subject. In view of the importance of addressing durability of concrete ties in the AREA Manual, we recommend that this subcommittee assignment be continued until appropriate Manual recommendations are developed.

Subcommittee 5. Maintenance Requirements.

C5-1-87. Maintenance requirements of concrete ties, including pads and insulation.

The subcommittee has prepared a questionnaire that was forwarded by AREA headquarters to those railroads that have concrete tie track. Results of the questionnaires will be used in developing Manual recommendations for maintenance requirements of concrete tie track. In view of the increased usage of concrete ties, we recommend that this assignment be continued as an ongoing activity.

Subcommittee 6. Ballast Requirements.

C6-1-87. Collaborate with Committee 1 on concrete tie ballast requirements.

The subcommittee has continued collaboration with Subcommittee 1 and will continue to furnish data and recommendations concerning concrete tie ballast requirements. Committee 10 will retain the ballast requirements for concrete tie track in Chapter 10 until it is adequately covered in Chapter 1. We recommend that the subcommittee continue this liaison activity to insure appropriate coverage of ballast requirements for concrete tie track in Chapter 1 of the Manual.

Excerpts From Annual Report of A.R.E.A. Committee 11 - Engineering Records & Property Accounting

A. R. Ranuio, Chairman

Committee Activity:

The September 1990 meeting in Washington, DC was held to present a united industry request to the Interstate Commerce Commission for specific rule changes. These changes included the following:

1. Option to eliminate accounting for interest during construction.
2. Reclassification of cost of computers from account 59 equipment to account 46 roadway.
3. Option to eliminate record keeping by valuation sections.
4. Option to no longer maintain signed Completion Reports on all capital projects.
5. Substitute a database for the Record of Property Changes manual ledger.
6. Revise list of acceptable reportable units (i.e. mbms of lumber to linear feet of trestle).
7. Increase the minimum rule for capitalization of property from \$2,000 to \$5,000.

At the committee's March 1991 meeting in Chicago, we carefully selected wording for the formal letter requesting ICC rule changes 1, 3, 4, 5, & 6 from above.

Excerpts From Annual Report of A.R.E.A. Committee 12 - Rail Transit

D. D. Dali, Chairman

Report on Special (D) and Continuing (C) Assignments

Assigned Number	C-1-87	C-2-87	C-3-87	C-4-88	C-5-89
Description of Assignment	Transit Corridors	Transit Trk. & Rdwy. Cons.	Stations Structures	Elect./Signals For Transits	Gen. Info. Rail Transit
Date Assigned/(Undertaken)	6/86	6/86	6/86	3/88	3/89
Estimated % Completion	100%	80%	75%	20%	50%
Estimated Completion Date	6/91	3/92	3/92	3/92	3/92
Problems	None	None	None	None	None
Recommend Assignment Being Dropped/(Discont.)	No	No	No	No	No
Recommend Assignment Being Postponed	No	No	No	No	No

Excerpts From Annual Report of A.R.E.A. Committee 13 - Environmental Engineering

W. M. Cummings, Chairman

Status of Subcommittee Assignments:

Subcommittee 1 — Water Pollution Control.

Assignment C1-2-86 — Report on Stormwater Runoff Regulations, has been an ongoing task due to EPA changes and delays in finalizing regulations. The regulations were finalized in mid-1991, draft report for Bulletin publication is under Subcommittee review. Assignment D1-3-88 — Groundwater Remediation, all sections complete and undergoing Subcommittee review.

Subcommittee 2 — Air Pollution Control.

Assignment D2-1-84 — Revision of Manual, all revisions completed. Ballot was completed at September Committee meeting and is to be submitted for Manual change shortly.

Subcommittee 3 — Land Pollution Control.

Assignment D3-1-90 — Minimization of Wastewater Treatment Sludges. Subcommittee members selected, initial request for information from individuals requested from entire committee at September meeting.

Subcommittee 4 — Noise Pollution Control.

This Subcommittee remains inactive.

Subcommittee 5 — Plant Utilities.

Assignment D5-1-82 — Revision of Manual, all sections have been revised. Upon clarification of numbering of one Section with Headquarters changes can be published. Assignment D5-7-91 — Above Ground Fuel Storage Tank Spill Prevention, this assignment was initially

questioned by Headquarters and has been corrected, Subcommittee members selected and initial request for information requested at September meeting.

In order to advance current topics in a more timely manner, the entire committee membership has been divided between the active assignments.

Excerpts From Annual Report of A.R.E.A. Committee 14 - Yards and Terminals

J. S. Acs, Chairman

Status of Subcommittee Assignments:

Subcommittee A — Recommendations for Further Study and Research

Presently there are a number of subjects under evaluation to determine the validity of future considerations:

1. Automatic Car Identification Systems.
2. Coach Yard support facilities for Commuter/Passenger Operation.
3. Environmental considerations relative to Yards & Terminals.

Subcommittee B — Revision of the Manual

There are no proposals under study for Revision of Manual at this particular time.

D-5-91 — Security at Auto Terminals.

New assignment, subcommittee is being organized.

D-1-90 — Design of Double Stack Facilities.

Final draft of the study is being formulated. Report should be available for publication in the Summer of 1992.

D-8-88 — Bulk Fluid Transfer Facilities.

The subcommittee has been riddled with problems. Since there are too many probabilities of material transfer, the subcommittee reorganized. Initial report should be available in the Summer of '92.

D-3-84 — Run Through Trains Effect on Yards

This study began in 1983 under the direction of four (4) different chairmen. Present chairman progressing the work with subcommittee study. This subject will be systematized and the projected preliminary report will be available in the summer of next year.

D-4-86 — Control of Cars with Contaminated Wheels.

The subcommittee made some progress with changes initiated by the second chairman at the helm. However, due to the chairman's present health condition, the progress is slow.

C-2-88 — Working with "TRB" on Intermodal Terminals.

This is an on-going effort to coordinate AREA/TRB activities within the set guidelines of both organizations. Basically, this is a one man subcommittee in an advisory capacity to report and monitor TRB activities and coordinate periodical conference attendance with our committee members.

D-1-90 — Fueling and Sanding Facilities in yards.

The subject is near to completion. Final report should be available at the end of this year.

D-7-87 — Yard Control Systems.

The first half of the report is completed and approved by the committee members. The final portion of the report is under preparation. Publication should be available by middle of next year.

D-2-89 — Rail/Water Transfer Facilities.

Study progressing, data is presently being circulated within the subcommittee. Report should be available for Bulletin distribution by December, 1992 and Technical Manual format by March, 1993.

Excerpts From Annual Report of A.R.E.A. Committee 15 - Steel Structures

M. Noyszewski, Chairman

Brief status of subcommittee assignments:

Subcommittee A. Recommendations for Further Study and Research

Our committee members are continuing to work closely with the AAR/NSF Bridge Research Program through our member John Choros of the AAR Technical Center. The Bridge Research Steering Committee for this program includes 5 members of Committee 15.

Subcommittee B. Revision of Manual.

The Committee has been working to prepare this year's submittal for changes to Chapter 15 of the AREA Manual and is working closely with other subcommittees on proposed future changes.

Subcommittee 1. Design Loadings and Stresses

D1-1-87. Obtain data from which the frequency of occurrence of maximum stress in steel railway bridges may be determined under service loading.

This subcommittee is working with the rating subcommittee and as the results of the current AAR/NSF Bridge Research Program are broadened to cover a sufficient number and variety of structures, the results will be put into a preliminary document. The analytical data (Scott Beisler's report) is ready but will not be issued until sufficient field corroboration is available.

Subcommittee 2. Materials

C2-1-82. Develop fracture control plan.

This assignment has been essentially completed and the appropriate elements are now in the AREA Manual. However, the fracture control plan will require updating as additional data becomes available and request that a new assignment be assigned the committee titled "Review and Update Existing Fracture Control Plan."

Subcommittee 3. Fabrication and Erection

C3-1-86. For steel fabrication develop materials, methods, quality control procedures and qualifications of fabricators.

The Subcommittee continues to work on the development of specifications for the loading details for fabricated members, updating fabrication and erection specifications to reflect current practices, and other recommended changes in the area of fabrication and erection.

Subcommittee 6. Repairs and Maintenance

D6-1-88. Develop methods for repairing damaged steel bridge members.

Presentations have been made to the committee during the past year, and additional presentations are scheduled. It is estimated that at least two more years will be necessary to complete this assignment.

Subcommittee 7. Special Types of Construction and Miscellaneous

D7-1-87. Develop specifications for the design of confined elastomeric bearings in collaboration with Committee 8.

The subcommittee continues to develop a comprehensive specification for elastomeric bearings with the goal of establishing a selection matrix based on this specification.

Subcommittee 8. Commentary and Bibliography

C8-1-60. Develop bibliography and technical explanation of various requirements in AREA specifications relating to iron and steel structures.

This assignment is being progressed. There is a continuing need for this committee to update and add items in its area of responsibility.

Excerpts From Annual Report of A.R.E.A. Committee 16 - Economics of Plant, Equipment and Operations

M. W. Franke, Chairman

Report on Special (D) and Continuing (C) Assignments*

Assigned Number	C1-1	D3-2-87	D4-1-87	D5-1-89
Description of Assignment	Manual Revision	Artificial Intelligence	Institutional Restraints	Dispatching Function
Date Assigned/(Undertaken)	Ongoing	1987	1987	1989
Estimated % Completion	Ongoing	75%	20%	90%
Estimated Completion Date	Ongoing	9/92	12/93	6/92
Problems	None	None	Project hard to structure	None
Committee Priority Number	*			
Recommend Assignment Being Dropped/(Discontinued)	No	No	No	No
Recommend Assignment Being Postponed	No	No	No	No

*Chapter 16 - Parts 1, 2, 3 and 4 being currently reviewed.

Excerpts From Annual Report of A.R.E.A. Committee 17 - High Speed Rail

R. D. Johnson, Chairman

Status of Subcommittee Assignments:

Subcommittee D-1-89. Corridor Evaluation

- A. Assigned January 26, 1989.
- B. The areas of investigation which have been identified by the Subcommittee are being developed and expanded by individual members.
- C. Completion is too early to determine.
- D. The benefits will be a standard of evaluation criteria which does not now exist.
- E. No problem areas.
- F. Continue activity.

Subcommittee C-1-89. Track, Structures, and Track Train Interactions

- A. Assigned January 26, 1989.
- B. An outline for the Subcommittee was discussed with General Categories of Definitions, Design, Construction Practice, and Maintenance Practice. Various detail sub-listings are being defined under these headings. Alignment and track loading portions within these detail sub-listings are being reviewed in detail.
- C. Completion date is too early to determine.
- D. The benefit will be a standard of evaluation criteria which does not now exist.
- E. No problem areas.
- F. Continue activity.

Subcommittee C-2-89. Vehicles, Control, and Propulsion System Considerations for High Speed Rail, Collaborating on Electrification with Committee 33 - Electrical Energy Utilization, and the AAR Communication and Signal Division.

- A. Assigned January 26, 1989.
- B. A draft section on Catenary/Pantograph Dynamics is under review and discussion. A draft performance outline statement on Signal/Train Control and Communications is undergoing editorial revisions and refinements prior to Subcommittee approval. A Subcommittee activity relating to detectors, both on board and wayside, has been established.
- C. Completion is too early to determine.
- D. The benefit will be a standard of evaluation criteria which does not now exist.
- E. No problem areas.
- F. Continue activity.

Subcommittee D-2-89. Evaluation of Systems for Operation Over 250 M.P.H.

Not assigned for study yet.

Excerpts From Annual Report of A.R.E.A. Committee 18 - Light Density & Short Line Railways

R. A. Paul, Chairman

Status of Assignments:

Subcommittee A — Recommendations for further study and research.

It is recommended that assignments D-3 and D-4 be approved by the Board of Directors.

D-3 — Compile a list of the documents which describe the engineering assets of a railroad. The document resulting from this assignment is expected to be of value to someone who acquires a short line or light-density railroad, but who has not previously been involved in railroad operations.

D-4 — Develop recommended practices for budgeting and planning the engineering work of short line and light density lines.

Subcommittee B — Proposed Manual Chapter

B-1 — Review the current manual for its application to short lines. Added emphasis on cross tie specifications is being discussed.

B-2 — Examine deleted portions of the manual that may be valuable to short lines. Material has been forwarded by the AREA staff for the Subcommittee's review.

Subcommittee 1

C-1-90 — An inventory of rail and OTM of 100# and less has been completed and is being prepared for publication.

C-2-90 — Recommended practices for obtaining, maintaining, organizing and operating maintenance of way work equipment on shortlines.

Subcommittee 2

D-1-90. — Investigate special considerations for obtaining contracted engineering services for short lines. Suggested approach to this assignment includes preparing sample bid or contract forms for commonly-contracted undertaking such as tie replacement, lining and surfacing, rail replacement, highway crossing repairs, vegetation control, bridge inspection and repair, or trackwork design.

Considerable discussion was held on how the committee could best assist carriers with obtaining these services, and concerns such as legal liability to the committee which might result. It was decided that the committee can and should provide general guidance in the form of sample agreements for such services, listing major relevant items of concern and typical basic wording to cover them, but without attempting to provide specifics which would apply to any particular work on any particular carrier.

D-2-90 — Investigate inspection criteria for short lines. Work to date has focused on bridge inspections, with an emphasis on providing a track inspector with the minimum knowledge needed to determine when major problems exist, and hence when higher level assistance should be requested for bridge assessments and/or repairs. A draft has been produced to address this aspect of bridge inspection and review continues in the subcommittee.

Excerpts From Annual Report of A.R.E.A. Committee 22 - Economics of Railway Construction & Maintenance

S. H. Morrell, Chairman

Status of Subcommittee assignments:

Subcommittee B: Revision of Manual

- (a) Assigned: Unknown
- (b) Progress: Rewrite of entire Manual underway with progress of each part as shown in (e) and below.
- (c) Completion date: 6/92 per Committee's five-year goals.
- (d) Benefits: Greatly improved quality of information in Chapter 22 of Manual.
- (e) Problems: None. Parts 1, 2, and 4 are complete and were included in the 1991 Manual Update. Part 3 is in progress.
- (f) Recommendations: Continue.

Subcommittee B-1, Part 3. Revisions of Manual - Construction and Maintenance Operations

- (a) Assigned: 1/14/88.
- (b) Progress: 80% - Reviewing proposed changes.
- (c) Completion date: 6/92
- (d) Benefits: Improved information.
- (e) Problems: None.
- (f) Recommendations: Continue.

Subcommittee D-1-90. Renewal of Concrete Ties complete or in part.

- (a) Assigned: 1/29/90.
- (b) Progress: 0% - Reviewing Committee 10's work.
- (c) Completion date:
- (d) Benefits: Addresses an important and extensive topic.
- (e) Problems: None.
- (f) Recommendations: Continue

Subcommittee D-2-86. Economics of Various Surface Gang Consists used by Railroads in North America.

- (a) Assigned: 1/14/86.
- (b) Progress: 100%—Completed.
- (c) Completion date: 3/91.
- (d) Benefits: Information.
- (e) Problems: None.
- (f) Recommendations: Submit for publication

Subcommittee D-3-88. Economics of Vegetation Control Methods Working with Committees 1 and 13.

- (a) Assigned: 1/14/88.
- (b) Progress: 10%.
- (c) Completion date: 6/92.
- (d) Benefits: Develop costs of Vegetation Control Methods.
- (e) Problems: Change in chairman slowed progress. Reviewing prior efforts to determine whether to start over or continue based on prior information.
- (f) Recommendations: Continue.

Subcommittee D-4-90. Track Time Usage.

- (a) Assigned: 1/29/90.
- (b) Progress: 30% - Further clarification of the subcommittee's goals is needed.
- (c) Completion date: 6/92.
- (d) Benefits: Addresses economics of gang size and track time relationships.
- (e) Problems: None.
- (f) Recommendations: Continue.

Subcommittee D-5-87. Economics of Standardization of Turnout Materials.

- (a) Assigned: 1/87.
- (b) Progress: 100% - Published in October 1990 Bulletin 727.
- (c) Completion date: 6/90
- (d) Benefits: Can have significant impact on industry.
- (e) Problems: None.
- (f) Recommendations: None.

Subcommittee D-6-90. Centralized vs. Decentralized Renewal Planning.

- (a) Assigned: 1/29/90.
- (b) Progress: 10%
- (c) Completion date:
- (d) Benefits: Provide planning alternatives based on size, budget or other economic considerations.
- (e) Problems: None.
- (f) Recommendations: Continue.

Excerpts From Annual Report of A.R.E.A. Committee 24 - Engineering Education

J. W. Orrison, Chairman

Subcommittee Assignments:

Subcommittee A. Recommendation for further study and research.

Assigned: Prior to 1983

Progress: Subcommittee will be involved in assisting with review of establishing subcommittee goals for the future years and will be responsible for identifying topics that should be handled as recommendations for further study and research.

Completion: Should be continuous.

Benefits: Develop meaningful new assignments for the committee membership.

Problems: None.

Recommendations: Continue.

Subcommittee 1. Continuing Education (C1-1-71)

Assigned: Prior to 1983.

Progress: Exploring new alternatives to stimulate the participation of AREA's membership in continuing education activities.

Completion: Should be continuous.

Benefits: Provides opportunity for AREA members to improve their knowledge of subject matter which is relevant to the railroad industry.

Problems: None.

Recommendations: Continue.

Subcommittee 2. Student Relations

(C2-1-82) Recruiting of engineering graduates

(C2-2-88) Student Interest Award Program

(C2-3-71) Student Relations

Assigned: Prior to 1983.

Progress: Will publish an annual survey of college graduate hiring by railroad engineering and maintenance departments in the AREA Bulletin. Administers the AREA Student Interest Award Program (SIAP). (The subcommittee is involved in administering Award announcement, judging and selection of up to 10 papers for recognition to receive the awards).

Will progress all initiatives concerning student relations including the AREA Student affiliates Program.

Completion: Should be continuous.

Benefits: Increased student awareness of AREA and provide for their involvement with AREA as student affiliates.

Problems: None.

Recommendations: Continue.

Subcommittee 3. Faculty Relations

(C3-1-85) Faculty Relations

(C3-2-82) Speakers for student groups

Assigned: 1985.

Progress: The purpose of the subcommittee is to provide opportunity for the railway industry to stimulate faculty involvement in railroad-related engineering problems. Advise schools of availability of railroad speakers for student groups. Plan to develop speakers presentation library.

Completion: Should be continuous.

Benefits: Opportunity to develop increased interest in railway engineering on the part of engineering faculty.

Problems: None.

Recommendations: Continue.

Excerpts From Annual Report of A.R.E.A. Committee 27 - Maintenance of Way Work Equipment

J. J. Hannaford, Chairman

Subcommittee assignments:

Subcommittee A. Recommendations for further study and research.

The task of this subcommittee is directing the Committee toward new tasks, set goals and interface with REMSA group.

Subcommittee B. Revision of Manual

Bar Code Guidelines were approved and published as information. Table of Contents for manual was approved and updated Specifications for Roadway Machines were approved.

Subcommittee C-1-74. Reliability Engineering, as Applicable to Work Equipment

Railroad and equipment manufacturer questionnaire dealing with machine quality of roadway equipment was completed and distributed to Committee 27 members only.

Subcommittee C-2-83. Preventative Maintenance of Way Equipment

A Directional Precis was sent out to all members asking for their input regarding the subcommittee's direction and suggestions for Preventative Maintenance topics.

A Maintenance Management System has also been distributed to all members for review and input.

Subcommittee D-2-86. Computer Applications as Applicable to Work Equipment

An informational handout was distributed to all Committee 27 members regarding an overview of Union Pacific's Engineering Equipment Management System.

Subcommittee C-3-84. Maintenance of Way Equipment Safety

A list of safety items for roadway and work equipment was distributed and discussed with all members at the last Committee meeting.

Subcommittee D-1-77. Training Programs for Machine Operators & Maintainers

As recommended by the Board, Committee will exchange training programs, if they are, in fact, obtainable from other railroads.

A questionnaire has also been distributed regarding Operator Training.

Excerpts From Annual Report of A.R.E.A. Committee 28 - Clearances

K. W. Eich, Chairman

Subcommittee Progress

Subcommittee A. Recommendations for Further Study.

A subcommittee to work in conjunction with Committee 34 (Scales) to weigh double stack container shipments, would be of special benefit to Committees 7, 8, 15 and 28.

Subcommittee B. Revision of Manual.

Our graphics portion of the Manual is rather old and does need partial updating. One diagram has recently been updated and currently, another should be available on or about January 1, 1992.

Subcommittee C-1-62. Compilation of the Railroad Clearance Requirements of the Various States.

The Subcommittee plans to add Mexico to the list and submit a new updated diagram shortly.

Subcommittee D-6-89. Compilation of a comprehensive glossary and bibliography pertaining to the technical literature on railroad high and wide clearances.

Five (5) revisions to existing definitions have recently been balloted, although results are not available at this time.

Subcommittee C-3-85. Review of railway line clearances to develop improved user accessibility.

Due to his new responsibilities as committee secretary, the chairmanship of this subcommittee has changed hands. Current and past chairmen are working closely to bring this subcommittee up to date.

Subcommittee C-4-91. Research, report and provide equipment clearance diagrams (plates) as required.

A technical paper has been written proposing the adoption of a standard base car to be used by both engineering and mechanical personnel in calculating railroad clearances on curves. The proposed mechanical standard, is that currently used by A.R.E.A. Committee #28 (base car with truck centers of 50'-0"). The Subcommittee chairman met with the AAR mechanical division's car engineering Committee to discuss this proposal. The AAR committee expressed concern that the proposed change would cause a wider endswing, producing potential problems in classification yards. This issue is currently being researched and a report will be issued concerning the groups findings.

Subcommittee D-3-85. Conversion of "heavy capacity and special type flat car" section of the Official Railway Equipment Register, to Umler compatible format.

For convenience sake, it has been suggested that the private car fleet be incorporated into the heavy capacity section of this publication. Due to an extreme concern on the part of one particular committee member, we will be requesting a change in the Subcommittee chairman. Discussions are currently being held regarding the possible need to make this an ongoing subcommittee.

Subcommittee D-4-85. Research and develop book covering heavy duty car diagrams and ratings.

The rate of progress has moved well under the leadership of the new Subcommittee chairman. With the exception of one railroad, the Subcommittee has received car diagrams for all railroad owned heavy duty cars. An additional exception will be Conrail, where the entire fleet is not proposed, given the age and condition of the fleet. The private car fleet will not be addressed at this time but will be incorporated

as an addendum. This should essentially complete the Subcommittees project, and finalized information will be forwarded to A.R.E.A. headquarters within the first quarter of 1992.

Subcommittee D-6-89. Recommendations for a uniform electronic clearance message.

This subcommittee's report has been completed and is currently being placed in an acceptable format for incorporation into the Manual.

Excerpts From Annual Report of A.R.E.A. Committee 32 - Systems Engineering

D. E. Bartholomew, Chairman

Subcommittee Progress:

Subcommittee A. Recommendations for further study and research.

Subcommittee has investigated changes and additions to all subcommittee assignments and has reviewed the feasibility of the committee developing Manual material. Recommendations for assignment additions and revisions are listed under each subcommittee report.

Subcommittee 2. Engineering Management Systems

Disseminate information pertinent to design and implementation, including specific applications or techniques within the scope of railroad engineering.

Subcommittee 2 recommends that the subcommittee title and description be revised to read:

Engineering Management Systems - Review, research and disseminate information pertinent to design and implementation, including specific applications or techniques within the scope of railroad engineering.

C2-1-86 Research new applications for the use of personal and main frame computers.

This is an ongoing assignment. The subcommittee has prepared a survey of existing and proposed applications of the various member roads. Subcommittee research results is usually disseminated via Committee sponsored Symposiums, presentations at Committee Meetings, Proceedings Articles and the planned March Conference Presentation.

It is recommended that subcommittee task C2-2-86 be combined with this task and that the assignment description be revised to read:

Research new applications for the use of Information Technology that will assist in the management of Engineering Services, including research and recommendations for information gathering methods and techniques.

C2-2-86. Improve data gathering techniques.

This is an ongoing assignment. Active subcommittee work has been limited since reporting of earlier research at the Committee's "Symposium on Strategies & Tactics of Engineering Data Gathering" at the Toronto Fall Conference in August of 1989. It is recommended that this assignment be combined with assignment C2-1-86 and task number C2-2-86 be dropped.

Subcommittee 2 has been reviewing the possibility of accepting an assignment for the development of Manual material. In association with Subcommittee A it is recommended that a new task be assigned with the following description:

D2-1-92. Initiate the development of Manual material for Engineering Management Systems.

Initial work will be the development of a Table of Contents for the Manual Chapter, which will serve as an outline for future tasks, followed by development of a general introductory,

recommendation and conclusion section which will include a general high level Flow Diagram of recommended Engineering Systems and Applications.

Subcommittee 3. Systems Engineering Education

Collect and disseminate information to the Association membership by means of special features, seminars, demonstrations and printed material.

The subcommittee's proposal to make a presentation at the March 1991 Conference was not accepted by the Association's Board of Direction. The subcommittee is working toward gaining approval to make a presentation at the March 1992 Conference.

The subcommittee is working on presenting a Symposium in 1993 probably in conjunction with the B&B and Roadmasters Conference and REMSA Show in Denver. In association with Subcommittee A it is recommended that a new task number be assigned for this activity with the following description:

D3-1-92. Present a Symposium in 1993.

Tentatively the general symposium emphasis is planned to include a description of engineering systems and how they are used by the mobile (field) manager and how these systems affect the bottom line.

C3-1-78. Programming systems for engineering design and analysis problems.

This task description is an ongoing subject of many Symposiums that have been presented by the Subcommittee. Continuing the use of this title as a task description has been reevaluated. It is recommended that subcommittee task C3-2-78 be combined with this task and that the assignment description be revised to read:

Application of engineering information systems as related to design and analysis problems and maintenance practices.

C3-2-78. Application of computer graphics to railroad engineering.

This task description was the title subject of an earlier Symposium and has been a part on many Symposiums presented by the Subcommittee. Continuing the use of this title as a task description has been reevaluated. It is recommended that this assignment be combined with assignment C3-1-78 and task number C3-2-78 be dropped.

Subcommittee 4. Engineering Graphics Systems and Interchange Standards

Collect information from North American Railroads on graphic system uses and examine existing drawing transfer standards.

D4-1-86. Make recommendation for industry standard.

Work is continuing on this assignment. The subcommittee has disseminated surveys to determine the types of CADD equipment and systems used on the various roads. Due to the rapid advance in technology this survey must be updated every few years. It is very difficult to make recommendations without favoring a specific popular equipment vendor. The subcommittee is, however, making progress toward developing a generic, albeit very general, recommendation. They are also looking at putting together a catalog of CADD specific information and reports and are investigating how various state highway departments are handling the standards problem.

It is recommended that subcommittee task C4-2-86 be combined with this task and that the assignment description be revised to read:

Develop a Manual section with recommended conversion and communication standards for CADD drawings to allow for electronic interchange of plans between various railroads and ventures.

D4-2-86. Research possible manual section of graphics standards.

The subcommittee is continuing to review the feasibility of developing manual material. The major obstacle is to avoid favoring a specific equipment vendor. Work is progressing in conjunction with assignment D4-1-86. The need for a separate task assignment has been reviewed. It is recommended that this assignment be combined with assignment C4-1-86 and task number C4-2-86 be dropped.

The subcommittee has had considerable involvement in researching ways of converting the drawings in the "Portfolio of Trackwork Plans" into CAD form. There have been a number of informal discussions with members of Committee 5. The two options of having various roads take responsibility for converting a certain number of drawings or of contracting out drawing conversion seem to be the most feasible. We understand that Committee 5 and the Association have chosen the latter option.

Excerpts From Annual Report of A.R.E.A. Committee 33 - Electrical Energy Utilization

J. Popoff, Chairman

Status of Subcommittee Assignments:

Subcommittee 1. (C1-1-73) Electrification Economics

This assignment was initially made in 1976 and is an ongoing review of the economic factors influencing the installation and maintenance of railroad electrification. An update bulletin was published as information in 1985. The committee is preparing an update for publication in early 1993.

Subcommittee 4. Railroad Electrification Systems**C4-1-76. Railroad Electrification Systems**

This assignment was initially made in 1976 and consists of a review of the specifications and guidelines for the systems and major components comprising railroad electrification. The section regarding poles and footings was published in 1991. The Committee is currently producing updated recommendations regarding physical and electrical clearances appropriate to North American electrification. The Committee is incorporating operating experience and research efforts from Europe and Canada.

D4-1-87. Electrification Safety

This assignment was made in 1987 for the review of safety requirements associated with the construction and operational maintenance of electrified systems. This assignment has been discussed with a Board member and determination of legal ramifications are still being discussed.

Subcommittee 5. (C5-1-76) Signals and Communications

This assignment was made in 1976 and consists of an ongoing review of the interface requirements between railroad electrification and the signals and communications equipment. The Committee has agreed to temporarily suspend work on this assignment to concentrate on the completion of the other assignments.

Subcommittee 6. (C6-1-76) Power Supply and Distribution

This assignment was made in 1976 and consists of an ongoing review of the specifications for the power supply and distribution systems required for railroad electrification. The power utility section

has been circulated and approved by the subcommittee and will be presented to the Committee for comments and balloting in early 1992.

The subcommittee is currently preparing the draft of the electromagnetic interference section.

Excerpts From Annual Report of A.R.E.A. Committee 34 - Scales

F. J. Loyd, Jr., Chairman

Activities of Subcommittees:

Subcommittee A. Recommendations for Further Study and Research

This is an ongoing subcommittee.

This Committee investigates and reviews products and technological changes in the industry and makes recommendations to the Committee chairman concerning need for further study and research.

Two items were identified by the Committee to be addressed pertaining to: (1) Railroad Master Scale Program and (2) Recommended Track Scale Testing Criteria. The Board approved the formation of a subcommittee to study Item 1, which began in 1990.

A subcommittee to study the "Railroad Master Scale Program" was approved by the Board for creation in 1991. Subcommittee members, a Chairman and Vice-Chairman were assigned in the Spring, 1991, meeting.

Subcommittee B. Revision of AAR Scale Handbook

This is an ongoing subcommittee.

There have been no changes to the AAR Scale Handbook approved in the past year; however, the changes voted on at the National Conference on Weights and Measures, effective January 1, 1991, were included in the Handbook in 1991.

This Subcommittee is one of the most important within Committee 34 because of the critical need to keep the AAR Scale Handbook up to date with technological advances, State and Federal Laws, etc.

Subcommittee C-1-85. Preparation of Subjects for Publication

This is an ongoing subcommittee.

Changes to the AAR Scale Handbook to bring it into conformance with NIST H44 (State and Federal regulations) will be upcoming. There are currently no outstanding assignments pending. The paper entitled "Criteria for Location of Coupled-in-Motion Weighing Systems," prepared by Subcommittee D-1-83, was finalized June, 1990, and published in the December, 1990 AREA bulletin. Also AAR Circular OT-17-F, "Recommended Practices for Inspecting, Testing and Repairing Industry Track, Vehicle, Hopper Type and Belt Conveyor Scales" was updated with input from Committee 34 and republished June 1, 1990. It was published in the October, 1990, AREA bulletin.

Subcommittee C-2-82. Innovations in Scales Used in Connection with Operations of Railroad

This is an ongoing subcommittee that investigates new technology and changes in the weighing industry that affect railroads.

The Subcommittee is planning to study a Chronas-Richardson "High Speed" system to be located on the Burlington Northern in Kansas City, Kansas when Kaman Science decided to discontinue development of their system. Items being studied deal with high speed Coupled-in-Motion weighing as related to accuracy and to the benefits to the railroad industry.

Subcommittee D-1-83. Criteria for the Location of Coupled-in-Motion Track Scales

A number of this subcommittee's members were associated with the National Conference on Weights and Measures S&T Railroad Advisory Committee, which developed considerable data and information concerning topographical situations for Coupled-in-Motion systems.

The final draft of this study was published in the December, 1990, AREA bulletin. This Subcommittee will continue to conduct further studies correlated with the NCWM S&T Committee study of coupled-in-motion individual car weights used for custody transfer.

Subcommittee D-2-87. Investigate Stenciling of Cars Using Coupled-in-Motion Weights

This Subcommittee, under the direction of the new Chairman has made substantial progress. Questions concerning how cim light weights could be applied/usage guidelines have sparked further considerations for the subcommittee's study. Historical data concerning empty car weights and the economic implications, of the present tare weighting program vs. a modified program using coupled-in-motion weights are factors with relevant effect on the subcommittee's study.

The Mechanical Division of the AAR have been consulted for input concerning the future direction and focus of the study.

Subcommittee D-3-90. Track Scale Testing Guidelines, Test and Inspection Forms

This Subcommittee has begun researching various test reports and will plan to meet to study the various forms and guidelines in place on the different railroads.

Subcommittee D-4-91. Railroad Master Scale Program

This newly formed Subcommittee will study the existing master scale program concerning the railroad's needs, as well as alternatives to existing type of master scale. It will study the effects of the newer ram-type and heavier scale test cars on the existing scales, and determine if procedures are needed to protect the existing scales.

Proposed Manual and Portfolio Revisions

The following proposed Revisions of the A.R.E.A. *Manual for Railway Engineering and Portfolio of Trackwork Plans* have been recommended to the association by the technical committee responsible for each after a letter ballot is approved by: (1) a two-thirds majority of the eligible members voting, and (2) by at least fifty percent of the total eligible voting members on the committee. They are being published here for comment of the general A.R.E.A. membership and any other interested parties. Comments should be sent to A.R.E.A. headquarters by March 1, 1992. These comments will be considered by A.R.E.A. Board of Direction in deciding whether to give final approval for inclusion of the proposed changes in the Manual and Portfolio Revisions which if approved go into effect August 1, 1992.

Proposed 1992 Manual Revisions To Chapter 1 - Roadway and Ballast

Proposed revisions to Chapter 1 include addition of a Glossary to Part 3 — Natural Waterways, and in Part 4—Culverts there is a rewriting of existing Sections 4.14 Jacking Culvert Pipe Through Fills and 4.15 Methods of Installing Culverts Inside Existing Culverts. The rewritten Section 4.14 will contain newly added information on earth boring of culvert pipe and be retitled “Earth Boring and Jacking Culvert Pipe Through Fills.” Section 4.15 was rewritten to include consideration of other methods of culvert rehabilitation or repair and will be titled “Culvert Rehabilitation.”

The proposed material for Parts 3 and 4 follow:

3.7 GLOSSARY

Aggradation

The active buildup of a streambed due to deposition of material.

Alluvium

Stream-transported material deposited in a sorted manner on a streambed or its flood plain.

Antecedent Moisture Condition

The relative soil moisture at the beginning of a runoff period.

Areal Precipitation Distribution

The distribution of precipitation over a specific area.

Artificial Obstruction

A man made obstacle which impedes, deflects or changes in some other manner the flow characteristics of a stream.

Backcurrent

Water currents that are retarded or turned back by an obstruction or opposing currents.

Backwater

A condition that occurs in a flowing stream, when a dam or other obstruction exists, which has the net effect of raising the water level.

Bedding Layer

The layer of earth or other type material on which a pipe or conduit is supported.

Channel Cut-Off

A channel realignment designed to straighten a stream or bypass large bends, thereby relieving flood susceptible areas from erosion.

Check Dam

A dam designed to control streambed erosion by retarding water flow in the channel.

Clear-Water Scour

A type of scour where material is removed from the scour hole and not replaced.

Cohesionless Soil

Soil that possesses little shear strength when air-dried and low cohesion when submerged.

Crib Dike

A permeable dike installation consisting of several log cribs, filled with rock, cabled together projecting into a streambed. Crib Dikes are commonly used where the waterway bottom is bedrock.

Culvert

A conduit conveying a stream of water through or parallel to a railway embankment.

Curve Number Method

A method developed by the Soil Conservation Service which determines the quantity of runoff from a given amount of precipitation and considers the effects of basin soil and cover types, rainfall depth and antecedent moisture conditions.

Debris

Any material including floating woody materials, ice and other type trash suspended and moved by a flowing stream.

Degradation

The lowering of a streambed due to increased scour action.

Dikes, Jetties, Groins

Structures designed to either slow current velocities of sediment-carrying streams causing a resultant deposition (permeable structure) or divert or deflect the flow away from an erodable surface (impermeable structure).

Discharge (Q)

The rate of water flow expressed in terms of volume per time such as cubic feet per second, gallons per minute, millions of gallons per day, etc.

Drainage Basin Area (A)

Area of watershed in acres.

Drainage Structure

A structure designed to control and/or transmit water flow through or parallel to a line of railroad.

Drawdown Effect

The associated loss of stability due to an increase in the driving force accompanied by the reduced soil strength in a roadbed embankment caused by rapid lowering of a bordering water body; the rate of water body lowering is more rapid than the rate of drainage from the roadbed.

Drift

See Debris.

Effective Fetch (F)

The length of reservoir across which wind blows to create wave run-up against dam face; the direction is usually normal to the dam, although where winds can be channelized, such as in a gorge, the path may be curved.

Embankment

A mass of soil, rock or other type material constructed above the natural ground surface.

Erosion

The wearing away or removal of the land by weathering processes such as by wind and water.

Exceedence Probability

The probability that a specific peak discharge will occur or be exceeded.

Fence Jetty

A permeable jetty installation designed to promote siltation by utilizing a series of vertical members along with wood or wire fencing material. Fence Jetties can be constructed parallel as well as transverse to the stream flow.

Floods

Relatively high flows, in terms of either water level or discharge.

Foreshore

The strip of shore land between a stream and occupied property.

Gabions

Specially designed, stone-filled baskets made from wire or plastic mesh and used primarily as retaining structures, revetments or check dams.

Hardpoint

See Dikes, Jetties, and Groins.

Heading

Back-up of water above the designed maximum flow.

Hydraulic Capacity

The maximum water flow through a structure.

Impermeable

The inability to transmit water flow.

Impervious

Material of low permeability, generally resisting entrance of liquids.

Infiltration

The flow or movement of water into soil or porous rock.

Interface

A boundary between two distinctly different materials.

Laursen Scour Design

A graphical method used to predict the depth of scour in a streambed. It is generally considered to be applicable for the clear-water scour case.

Leeward

The side or direction opposite that from which the wind is blowing; towards the sheltered side.

Liquid Limit (LL)

The moisture content boundary between the liquid and plastic states of a soil.

Littoral Current

The results of waves breaking at an angle on the shoreline.

Log Pearson Type III Distribution

A federally mandated statistical analysis to estimate the probability that a given magnitude of flow can occur or be exceeded.

Meander

Freely developing curves or bends in the course of a stream.

Minimum Wind Duration (t_a)

The time in minutes, for wind at a constant velocity over a particular fetch, to produce waves of a maximum height for that wind velocity.

Neville Sediment-Transport Scour Design

An analytical method used to estimate the depth of scour in a streambed. It is generally used for the sediment-transport scour case.

Overtopping/Overflowing

Any amount of water which exceeds the design capacity of the individual structure.

Permeable

The ability to transmit water flow.

Pilot Channel

One of a series of channel cutoffs built for changing a meandering stream to a straighter channel of greater slope.

Piping

Subsurface erosion caused by water percolating or moving through a soil layer forming narrow conduits or tunnels through which soil is removed.

Propeller Backwash

The backward movement of water due to the mechanical action of a boat motor.

Rainfall Intensity (i)

The average rainfall value in inches/hour during the time of concentration.

Rational Method

A common method employed in the determination of peak runoff rates for drainage facility design. In this design method, the peak flow $Q_p = ciA$ where c is a dimensionless runoff coefficient, i is the rainfall intensity in inches/hr. and A is the drainage area size in acres.

Refraction

The change in the direction of a wave moving in shallow water at an angle to the bottom contours.

Return Period (T)

The predicted interval of time a certain flood level will likely be reached or exceeded.

Revetment

A shell or covering of stone, concrete, gabions or other type materials for embankment protection against erosion.

Rock Jetty Dike

An impermeable dike installation consisting of stone-filled structures placed intermittently along a stream bank. Rock Jetty Dikes are effective protection for banks along streams carrying minimum sediment loads.

Runoff Coefficient (c)

A dimensionless parameter, used in the Rational Method of waterway capacity design, which estimates the percentage of precipitation that will become runoff. The coefficient value is between 0 and 1 and is influenced by climatic conditions and physiographic characteristics of the drainage region.

Scour

The removal of streambed material due to the action of streams, tides, propeller backwash, etc.

Sediment Deposition

An accumulation of soil particles on the streambed and bank.

Sediment-Transport Scour

A type of scour where the scour hole is continuously supplied with the material from the sediment load carried by the stream.

Sheet Pile

A pile with a relatively flat and wide cross section, normally driven side by side to form a wall. Sheet Piles can be made of various materials; the most common being steel, wood and concrete.

Significant Wave Height (H_s)

Height of highest 1/3 of waves in a wave train.

Silting

The deposition or accumulation of suspended silt particles, generally occurring when waterflow is retarded. The term is often applied to any sized particles ranging from clays to sands.

Specific Wave Height (H_0)

The design wave height which is exceeded by the allowable percentage of waves in a wave train.

Spur Dike

A structure, projecting into a stream, designed to alter the water flow characteristics by deflecting erosive currents away from the stream bank.

Storm Duration (t)

Duration of a storm event in minutes.

Surface Runoff

Precipitation that does not infiltrate the ground surface.

Temporal Precipitation Distribution

Seasonal distribution of precipitation.

Timber Pile Dike

A permeable dike installation utilizing several spurs of timber piles driven at regular spacings. Timber Pile Dikes are most effective on heavy sediment-carrying streams.

Time of Concentration (t_C)

Time required for runoff to flow from the most remote part of the drainage area to the drainage structure.

Undermining

The action of eroding away supporting material.

Ultimate Total Abstraction (S)

The potential maximum water retention of a basin. It is the sum of the total infiltration and amount of water required to initially wet the surface and fill surface depressions.

Velocity (V) - Water

The speed of water flow expressed in terms of distance per unit time, typically as feet per second.

Velocity (U) - Wind

The speed of wind flow expressed in terms of distance per unit time, typically as miles per hour.

Washout

The failure of a culvert, bridge, embankment or other type structure resulting from the action of flowing water.

Watershed

The region drained by, or contributing water to, a structure, a stream or river system.

Wave Length (L)

Horizontal distance separating successive crests of a wave train.

Wave Period (T)

Time between passage of a given phase of one wave and arrival of same phase of next succeeding wave.

Wave Run-up (R)

Distance water will travel up the face of a dam when waves break against that dam face.

Wind Tide (S)

An increase in water level elevation due to the effect of wind-driven water in the direction of the wind.

4.14 EARTH BORING AND JACKING CULVERT PIPE THROUGH FILLS

4.14.1 General

Where conditions are suitable, the installation of pipe culverts by jacking and/or earth boring can be a viable alternative to more standard methods of installation such as open cut or tunneling. Possible advantages of jacking or boring include:

- a) Lower cost
- b) Minimal interruption of traffic
- c) Minimal disturbance of roadbed

Costs may be higher, although not necessarily prohibitive, in unstable soils and embankments containing boulders, stumps, waste from rock cuts, or similar obstructions.

Before it is decided that jacking is the proper method to use, all conditions involved in the operation should be investigated. Cost estimates for open cut placement or tunneling should be compared with the probable cost for jacking and/or boring. Such estimates should include expenses due to interference with traffic and excess maintenance until embankment becomes stabilized. Additionally, relative safety of the various installation methods must be considered. The exposed vertical face associated with the jacking operation may not be desirable in certain soil conditions and should be addressed by a qualified engineer.

It is recommended that pipe boring and jacking operations be performed by an experienced specialty contractor normally engaged in performing this type of service. Most railroad maintenance-of-way departments are not equipped to undertake such a project. Furthermore, if poorly done, a potential embankment failure could have catastrophic results with possible loss of human life and/or extensive property damage.

For further information on earth boring and jacking methods refer to "Horizontal Earth Boring and Pipe Jacking Manual" as published by the National Utility Contractors Association, latest edition.

4.14.2 Type of Pipe Suitable for Jacking

Ideally pipe materials to be used in the boring and jacking process should have a smooth exterior wall. The most commonly used materials for pipes installed by the boring and jacking contractor are smooth wall steep pipe or tongue and groove circular concrete pipe. Other shapes, such as precast reinforced concrete box sections and reinforced concrete elliptical pipe sections, have been successfully jacked. Under certain conditions, corrugated metal pipe can also be jacked.

Concrete pipe is manufactured with tongue and groove joints which provide a smooth outside surface. An appropriate class of concrete pipe should be selected to provide the compression strength to resist the axial forces imposed by jacking. Supplemental joint reinforcing may be required if eccentric loading of the joint is a possibility.

4.14.3 Size and Length of Pipe

The size of pipe that can be placed by jacking will vary with local site conditions. The jacking contractor and pipe manufacturer should be consulted regarding suitable size and length limits.

Concrete pipe sections are usually manufactured in eight foot lengths; however, other lengths may be available.

4.14.4 Precautions in Unstable Soils

The jacking method is not well adapted to placing pipe in unstable soils, unless certain precautions are taken. Before undertaking an operation of this kind a thorough investigation of conditions should be made. Borings into the fill where there is doubt as to the nature of the material may be desirable. Unstable soil conditions should be evaluated by a qualified geotechnical engineer for recommendations on the most appropriate method of soil stabilization.

If jacking is decided upon it will probably be beneficial to work continuously to minimize the tendency of the material to “freeze” around the pipe. However, lubricants such as bentonite slurry are available to minimize the freezing tendency. The approach trench should be properly sheeted and braced on the sides and working face. Wet sandy soils can be de-watered by various means including well points. The excavation should not be carried more than a few inches ahead of the pipe. If the pipe seizes, jacking may have to be done from both ends, or installation of intermediate hydraulic jacking stations may be required. In some instances, switching to trenching or open cut methods may be required.

Excessive voids shall not be permitted in the jacking process. Grout points shall be installed in pipe and all voids shall be filled by pressure grout as soon as possible after the completion of the project.

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4.14.5 Protection of Pipe Against Percolation, Piping and Scour

If it is anticipated that the pipe will discharge under head for any considerable period, and particularly if it lies in easily eroded material, precautions against percolation or piping along the outside should be taken.

Concrete collars, grout injected collars, cut-off walls, slope paving or similar impermeable slope barriers should be considered as a precaution against percolation or piping along the outside of the conduit.

Should it be necessary to protect the ends against scour, concrete pavement or riprap can be provided at the end of the pipe. In extreme cases energy dissipators can be used to reduce the outlet velocity of flow to acceptable limits.

4.14.6 Safety

Trenching is one of the most dangerous situations in modern construction. Since a jacking operation generally involves some form of trenching or pit construction, the jacking contractor or railway forces must strictly conform to all Federal, State and local regulations and in particular, the requirements of the Occupational Safety and Health Administration (OSHA).

4.15 CULVERT REHABILITATION

4.15.1 General

The purpose of this part of the Manual is to guide the design engineer in his decision to rehabilitate or replace deteriorated or failing culverts and to recommend methods for the culvert rehabilitation or repair.

While the magnitude of rehabilitation may at times appear enormous, rehabilitation often is very cost effective when compared to the alternative of new construction.

It is recommended that a regular program of culvert inspection and evaluation be instituted to identify deteriorated and/or failing culvert sections.

4.15.2 Survey of Existing Structures

Once a problem is identified, a careful survey should be made of the existing structure to determine the exact size and shape. It is necessary to know the exact cross-section of the opening at all limiting points, the alignment of the structure with respect to its centerline, and whether projecting parts of the existing culvert can be removed. Any old falsework piling, boulders or ledge rock in the waterway that might interfere with rehabilitation efforts should be noted. In addition, the structural integrity of the culvert and the foundation conditions under the existing structure should be evaluated.

Given the above information, the design engineer can effectively consider the comparative advantages of rehabilitation or replacement of the culvert. Items of consideration should include:

1. Extent of critical nature of the deterioration.
2. Available track time.
3. Site accessibility.
4. Available time that flow can be restricted.
5. Useful service life/life-cycle cost analysis.
6. Required hydraulic capacity.
7. Environmental considerations.

4.15.3 Methods of Rehabilitation

If the decision is to rehabilitate the culvert, the design engineer has several options to consider. Methods of culvert rehabilitation include:

1. Localized repairs.
2. Reline the existing structure.
 - a. Slip line with slightly smaller diameter pipe or tunnel liner plate.
 - b. Inversion lining.
 - c. Shotcrete lining.
 - d. Cement mortar lining.

Other methods of pipeline rehabilitation are available, but some may not be practical for culverts.

4.15.4 Localized Repairs

In some cases it is practical to consider localized repair. This can be an economical solution when the overall condition of the culvert is still performing as designed but has isolated areas of deterioration that if left untended would lead to major problems in the future. Techniques that are available to the engineer include:

1. *Grouting*: Voids in the backfill caused by leaking joints or pipe wall perforations can be filled by pumping a sand-cement mortar grout into the void. This can be done from the inside if the structure is large enough or from the outside of shallow buried structures. Filling the void with grout should prevent further loss of backfill.
2. *Patching*: Localized damage to linings, coatings or pavements in culverts can be patched or prolong the life of a drainage structure. The area to be repaired should be properly cleaned and the repair material should match the original material if possible.
3. *Internal Expanding Bands*: Pipe joints that have become separated to a degree where loss of backfill is a threat to the grade of the track above the structure can be repaired with bands couplers that are tightened from inside the pipe. These bands then expand against the inside wall to form a seal.
4. *Sealing*: Elastomeric grout can be used effectively to seal and prevent loss of fine backfill through open pipe joints. This grout is mechanically pushed into the open joint with the aid of an inflatable bladder. The chemical grout turns into an elastomeric seal immediately upon contact with water. This material is normally not used to fill voids because of its cost.

4.15.5 Relining Materials

The selection of the reline material is dependent upon the condition of the conduit to be rehabilitated and its diameter and/or shape. If the line has deteriorated to the point that it is structurally deficient, the rehabilitation should have sufficient structural capability to withstand the imposed dead and live loads.

4.15.5.1 Sliplining

If after hydraulic evaluation, the downsizing of the existing line is acceptable, then standard corrugated metal pipe may be used and provided in lengths which would facilitate insertion. Hydraulic advantages may be gained by improvements to inlet details (see Section 4.8.3.1) or by using helical corrugated steel pipe if the existing pipe is annual corrugated.

Hydraulic capacity can be maximized by the use of smooth lined metal pipe. Choices of this type of pipe include:

1. 100% asphalt lined.
2. 100% cement mortar lined.
3. Double-wall CMP.
4. Spiral rib CMP.

Connection of the liner pipe segments can be achieved with either internal or external adjustable bands depending upon the available clearance within the culvert.

If the culvert to be relined is large enough for a person to enter, "guide rails" may be installed to insure that the proper alignment and grade of the liner pipe is maintained. If the lining of the pipe is to be placed at the same grade as the pipe being lined, skid bars attached to the lining pipe are used in lieu of the guide rails. Also it is common practice to specify grout plugs and hold-down devices.

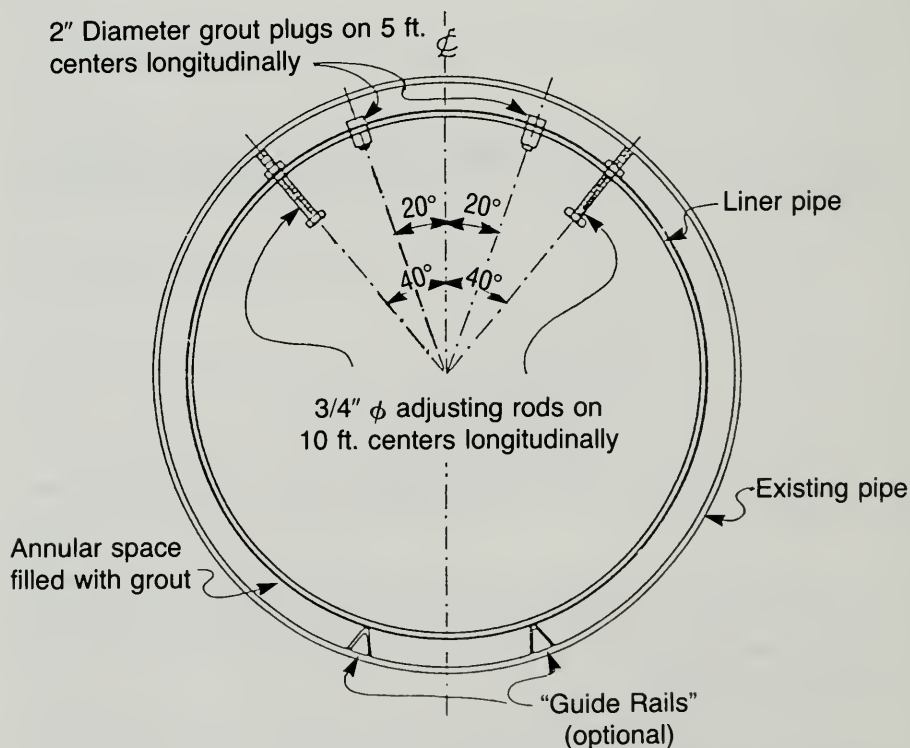


Figure 4.15.1 — CMP Liner Pipe Installation Showing Guide Rails, Grout Plugs and Adjusting Rods

Where physical constraints and/or safety concerns limit the use of the liner pipe sections, it may become necessary to use tunnel liner plates. This permits the entire assembly to be erected from inside the structure.

After the liner pipe has been secured in place, the annular space between the liner pipe and the existing culvert should be filled. Suitable fill material will vary depending on the type and size of structure, the area to be filled, the equipment available and the structural requirements. Typical materials (referred to CLSM, Controlled Low Strength Material) include cement or chemical grout, concrete slurry and sand.

Care must be taken during filling to eliminate voids. Filling must be done in a balanced fashion and in a manner that does not cause deformation of the lining pipe. The lining pipe may need to be internally braced (or externally blocked) to resist grouting pressure. The lining pipe may also need to be secured to resist flotation during grouting.

4.15.5.2 Inversion Lining

Inversion lining is accomplished by using needle felt, of polyester fiber, which serves as the “form” for the liner. The use of this method requires that the pipe be taken out of service during the rehabilitation period. One side of the felt is coated with a polyurethane membrane and the other is impregnated with a thermostating resin.

The physical properties of the felt and chemicals must be determined for the specific project.

Inversion lining is most commonly accomplished by specialized contractors in rehabilitation of sanitary sewers and storm sewers and is not often practical in current rehabilitation.

4.15.5.3 Shotcrete Lining

Shotcrete is a term used to designate pneumatically applied cement plaster or concrete. A gun operated by compressed air is used to apply the cement mixture.

When properly made and applied, shotcrete is extremely strong, dense concrete and resistant to weathering and chemical attack. For relining existing structures, the shotcrete typically is from 2 to 4 inches thick depending on conditions and may be steel reinforced.

4.15.5.4 Cement Mortar Lining

For small diameter pipe which is not easily accessible, a cement mortar lining may be applied.

This method involves the use of a mortar projection machine and an attached mechanical trowel. The assembly is pulled through the culvert as mortar is applied to the interior surface and troweled.

4.15.6 In Place Installation of Concrete Invert

In some cases, the deterioration of the culvert may be limited to the invert. The upper segment may still exhibit acceptable structural integrity and rehabilitation with a cast-in-place reinforced concrete invert may be an acceptable alternative.

This method is generally limited to larger diameter pipes where it is possible for a person to enter and work within the conduit.

Prior to placing the new invert, it is necessary to divert the stream flow, remove debris and loose material, and clean the area to receive the new concrete. Next, a reinforcing mesh or bars are secured to the original culvert. Then an appropriate thickness of concrete is applied to the invert and troweled smooth to conform to the shape of the bottom of the culvert.

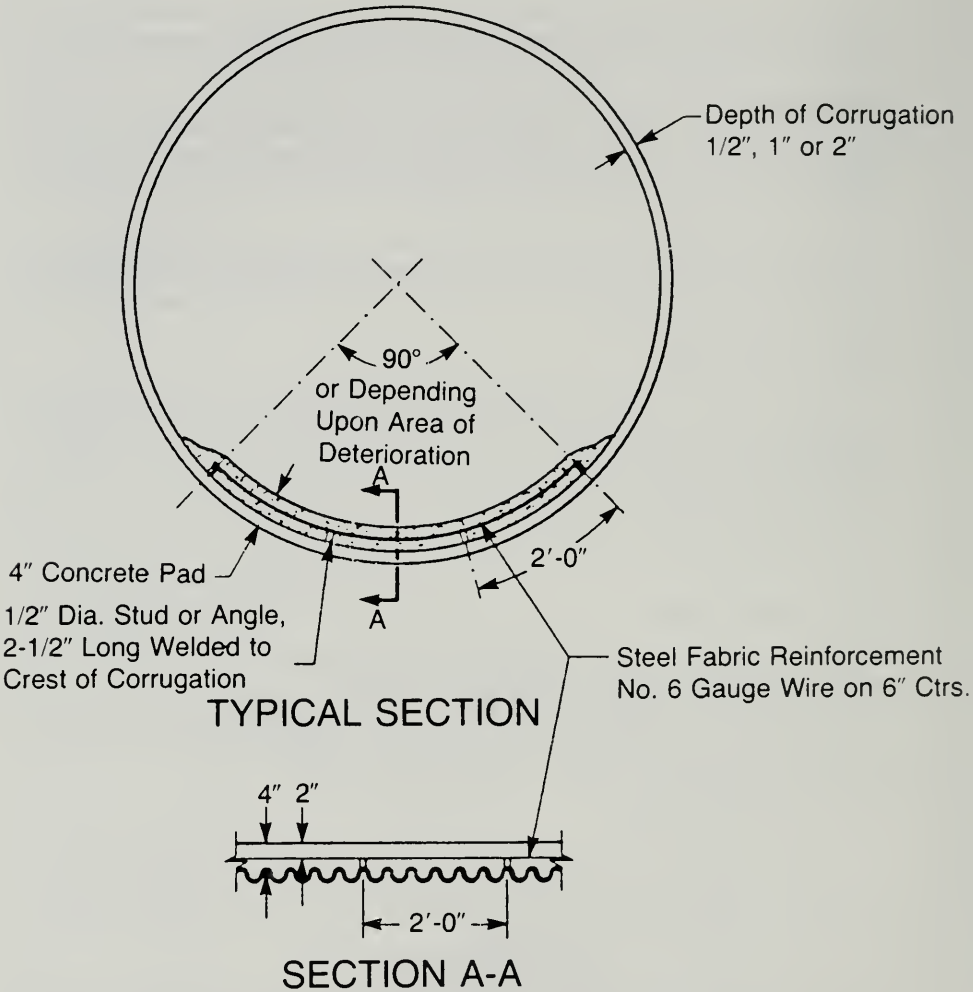


Figure 4.15.2 — Example of New Invert in CMP

An epoxy type sealer may be applied to the concrete invert to seal the concrete pores and increase service life.

The engineer or designer may also want to refer to Chapter 8, Part 14, *Repair and Rehabilitation of Concrete Structures*.

Proposed 1992 Manual Revisions To Chapter 2 - Track Measuring Systems

New Articles 1.3 Compilation of Various Track Geometry Parameters, 2.1 Description of a Generic Track Geometry Measuring Vehicle and 2.2 Recommended Minimum Performance Guidelines for Rail Testing are proposed to be added to Chapter 2. The new articles are as follows:

1.3 COMPILATION OF VARIOUS TRACK GEOMETRY PARAMETERS AND RELATED ELEMENTS, USED WHEN DESCRIBING TRACK GEOMETRY.

1.3.1 General

The purpose of this section is to describe the various track geometry parameters used by the railroads to describe track geometry. Included in this compilation is terminology for associated elements like rail, center line, etc.

Track geometry describes the position that each rail, or the track center line, occupies in space.

By projecting the track geometry into various planes, track geometry parameters can be specified. These parameters can be measured and used to describe track geometry.

Depending upon which plane they reside in, track geometry parameters can be grouped as follows:

- 1) parameters in the horizontal plane (a level plane defined by the horizon)
- 2) parameters in the longitudinal vertical plane (a vertical plane through each rail or the track axis)
- 3) parameters in the transverse vertical plane (a vertical plane normal to each rail or the track axis)
- 4) parameters in the track plane (a plane located 5/8" below the top of both rails along the track axis)

1.3.2 The Horizontal Track Geometry

The horizontal track geometry is called *Alignment*. Alignment is the projection of the track geometry of each rail or the track center line onto the horizontal plane. When alignment describes a rail, a line along the rail gage side, 5/8" below the top of the rail, is used for the projection. The following terms are used when describing alignment:

- (1) Curvature
- (2) Line
- (3) Degree of Curve
- (4) Curve Radius
- (5) Horizontal Space Curve
- (6) Versine

1.3.2.1 Measurements

The following measurements are used to quantify *Alignment*:

Absolute Horizontal Space Curve: Absolute geophysical location of alignment.

Chord Measurements: A chord is a straight line between two points of the alignment. The chord measurement is the horizontal projected distance between a point on the chord and a point on the alignment, perpendicular to the chord.

The following terms are synonyms for chord measurements:

- (1) Versine
- (2) Offset, Asymmetrical Offset, Symmetrical Offset, Mid-offset
- (3) Ordinate, Asymmetrical Ordinate, Symmetrical Ordinate, Mid-ordinate

Degree of Curve: The angle subtended at the center of a simple curve by a 100 ft. chord.

Horizontal Rate of Change: The horizontal difference between two alignment measurements of two points a preselected distance apart.

Quasi Horizontal Space Curve: Absolute geophysical location of alignment with its mean removed. The mean is calculated from alignment over a preselected distance.

Tangential Deflection: The angle between the chord and the tangent to the curve at one end point of the chord.

Tangential Offset: The distance measured perpendicular to the tangent between a point on the curve and the tangent.

1.3.3 The Longitudinal Vertical Track Geometry

The longitudinal vertical track geometry is called *Longitudinal Profile*.

Longitudinal Profile is the track geometry of each rail or the track center line projected onto the longitudinal vertical plane. When Longitudinal Profile describes a rail, a line along the top of the rail is used for the projection.

The following terms are used when describing *Longitudinal Profile*:

- (1) Profile, Surface, Top, Vertical Alignment
- (2) Dip, Sag, Hump
- (3) Grade, Slope
- (4) Ramps, Runoff
- (5) Vertical Space Curve
- (6) Vertical Curve

1.3.3.1 Measurements

The following measurements are used to quantify *Longitudinal Profile*:

Absolute Vertical Space Curve: Absolute elevation of each geophysical location of the *Longitudinal Profile*.

Chord Measurements

A chord is a straight line between two points of the *Longitudinal Profile*. The chord measurement is the vertical projected distance between a point on the chord and a point on the *Longitudinal Profile*, perpendicular to the chord.

The following terms are used when describing chord measurements:

- (1) Versine
- (2) Offset, Asymmetrical Offset, Symmetrical offset, Mid-offset
- (3) Ordinate, Asymmetrical Ordinate, Symmetrical Ordinate, Mid-ordinate
- (4) Dip or Hump if used on one rail only

Dip, Sag, Hump: The deviation of the vertical parameter of both rails from uniformity over a specified distance.

Grade, Slope: The vertical (or elevation) difference between two points of the Absolute Vertical Space Curve a preselected distance apart.

Quasi Vertical Space Curve: Absolute elevation of each geophysical location of the *Longitudinal Profile* with its mean elevation removed. The mean is calculated from *Longitudinal Profile* over a preselected distance.

Ramp, Vertical Runoff: The established change of elevation from one point to another along the track.

Vertical Rate of Change: The vertical difference between two *Longitudinal Profile* measurement of two points a preselected distance apart.

1.3.4 The Track Geometry in the Transverse Vertical Plane

Two parameters are used to describe the track geometry in the transverse vertical plane.

Superelevation: The difference in elevation between the top of one rail and the top of the other rail measured along a line perpendicular to the track center line.

The following terms are synonyms for superelevation:

- (1) Elevation
- (2) Cant
- (3) Crosslevel

Twist: The difference of superelevation of two points a fixed distance apart along the track (twist base).

The following term is a synonym for twist: Warp

1.3.4.1 Measurements

The following measurements are used to quantify the track geometry parameters in the transverse vertical plane:

- Actual Value
- Deviation from Design Value or Standard
- Deviation from Average (relative)
- Rate of Change: The difference between two measurements a preselected distance apart.

1.3.5 The Track Geometry in the Track Plane

Two parameters are used to describe track geometry in the track plane.

Gage (Gauge): The distance (measured normal to the track axis) between the inside of the rail heads.

Flangeway Width (Gap): The distance (measured normal to the track axis) between the running rail and the restraining or guard rail.

1.3.5.1 Measurements

The following measurements are used to quantify the track geometry parameters in the track plane:

- Actual Value
- Deviation from Design
 - Deviation from Average (relative)
 - Rate of Change: The difference between two measurements a preselected distance apart.

1.3.6 Related Terminology

Center Line: A line in the track plane equidistant between the gage lines of each running rail. Synonym: Track Axis.

Curve, Compound: A combination of two or more contiguous simple curves of different degrees having either a common tangent at their junction points or being connected with an easement curve.

Curve, Easement: A curve whose degree varies either uniformly or in some definitely determined manner so as to give a gradual transition between a tangent and a simple curve, which it connects, or between two simple curves. Synonym: Spiral or Transition (linear change of degrees)

Curve, Reverse: Two contiguous simple curves in opposite directions, without a common tangent at their junction point.

Curve, Simple: A constant change in direction of alignment.

Curve, Vertical:

- (1) An easement curve in the track to connect intersecting grade lines.
- (2) A parabolic curve used to connect two different grades of the center line of track (or track axis).

Field Side: The outside of the rails not used for guiding the wheels.

Flangeway Depth: The vertical distance from the top of the tread surface to the top of the filler or separator introduced between the tread portion and the guard portion of a track structure.

Gage Line: A line below 5/8" below the top along the gage side of the running rail.

Gage Side: The side of the rail head facing the centerline of the track.

Grade Rail: The inner or low rail in curves or either rail on tangent. Used for a basis of building and maintaining superelevation.

Guard Check Gage: The distance between guard line and gage line, measured across the track at right angles to the gage lines.

Guard Face Gage: The distance between guard lines, measured across the track at right angles to the gage lines.

Guard Rail: A rail or any other structure laid parallel to the gage side of the running rails of a track to prevent wheels from being derailed or to hold the wheels in correct alignment, preventing their flanges from striking points of frogs, points of switches or any other track structures. Synonym: Restraining Rail, Guide Rail.

High Rail: The elevated or outer rail in curves. Synonym: Line Rail.

Inner Rail: The rail with the smaller radius in a curve. Synonym: Grade Rail.

Outer Rail: The rail with the greatest radius in a curve.

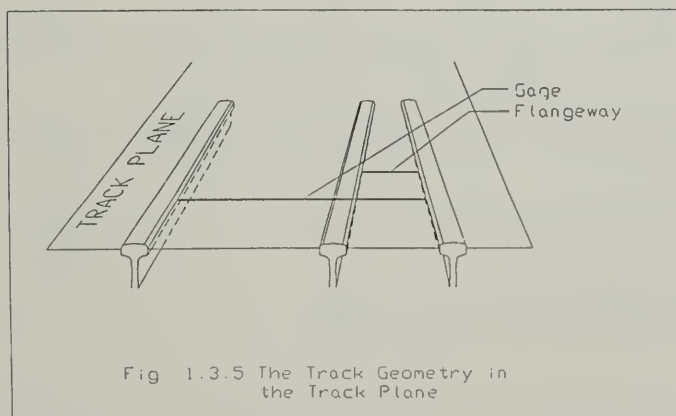
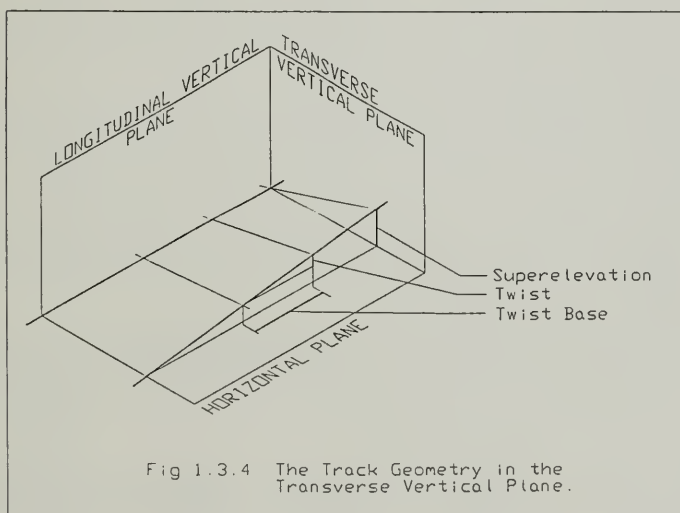
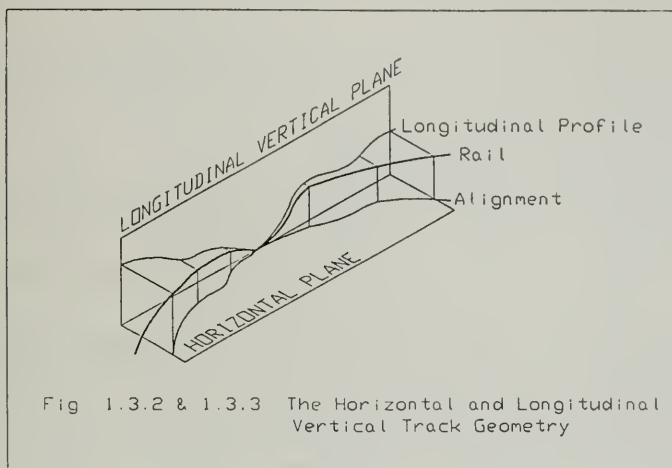
Platform Gage: The distance between the gage side of the running rail, measured in the track plane adjacent to the platform, and the closest point of the platform edge, next to the rail, measured in a plane parallel to the track plane.

Platform Height: Platform height is defined as the distance between the top of the running rail and the top of the platform (upper inner edge of the platform) measured in the transverse plane and normal to the track plane.

Power Rail: An extra rail used to provide power for propulsion. Synonym: 3rd Rail, Contact Rail.

Power Rail Gage: The distance between the gage side of the running rail, closest to the Power Rail, and the contact point of the adjacent side of the Power Rail, measured in the track plane. Synonym: 3rd Rail Gage, Contact Rail Gage.

Power Rail Height: The distance between the top of the running rail and the contact surface of the power rail measured in the transverse plane and normal to the track plane. Synonym: 3rd Rail Height, Contact Rail Height.



Reference Rail: The outer rail in curves. Used by maintenance machines to produce curve line.
Synonym: Line Rail.

Running Rail: The rail which supports the wheel.

Tangent: Any straight portion of the alignment.

Track: An assembly of rails, ties and fastenings over which cars, locomotives and trains are moved.

Track Axis: An axis defined by the longitudinal continuation of the track center line.

2.1 DESCRIPTION OF A GENERIC TRACK GEOMETRY MEASURING VEHICLE

The Track Geometry Measuring Vehicle is a single vehicle or complement of vehicles whose purpose is to measure and record the track geometry (refer to Article 1.3 "COMPILATION OF VARIOUS TRACK GEOMETRY PARAMETERS AND RELATED ELEMENTS, USED WHEN DESCRIBING TRACK GEOMETRY") in real-time, and to display this measurement.

Most Geometry Measuring Vehicles record distance as a consecutive number of scan distance intervals, converted into milepost and feet or kilometers and meters, providing an accurate means of locating points and known monuments or events along the track. Automatic Location Detector System (ALD) complements the distance detection.

The measured geometry parameters are compared to preset values to evaluate compliance to predefined standards. Points on the track that exceed these preset values are in exception and are listed as defects. Pin-pointing these defects can be facilitated by some means of marking.

The use of a magnetic tape or a floppy/hard disk system for storing of the raw, calculated or analyzed data obtained by the Geometry Measuring Vehicle allows the data to be used to determine short term and long term track degradation analysis. This is done by comparing the data of the current test with previous tests and noting the difference.

The use of highly advanced electronic devices and high speed computers allow the data to be collected at speeds up to 160 mph (250 kmh), with scan intervals of one (1) per foot or four (4) per meter. These processors are used in conjunction with high speed analog to digital converters, printer/plotters, monitors and mass storage devices.

A typical system consists of the following:

Distance Encoder: An optically coupled mechanical or magnetic pick up device that emits a specified number of pulses per revolution of a drive shaft. A preset number of pulses is equivalent to a known distance.

Input/Output Device: This device usually counts the encoder pulses and causes the input channels to be scanned at uniform distance intervals. It also allows the computer to control outside logic devices.

Measurement Device: Can be either a contact or non-contact device.

Most contact devices are coupled to a linear voltage displacement transducer (LVDT) that outputs an electrical value equivalent to the displacement of the measuring device value, relative to its null (zero) point.

Most non-contacting devices are based either on integrations of accelerations (created by a moving mass) or optical/camera systems.

Analog to Digital Converter: This device changes the electrical signal from the measuring device to a binary (digital) format supported by a computer.

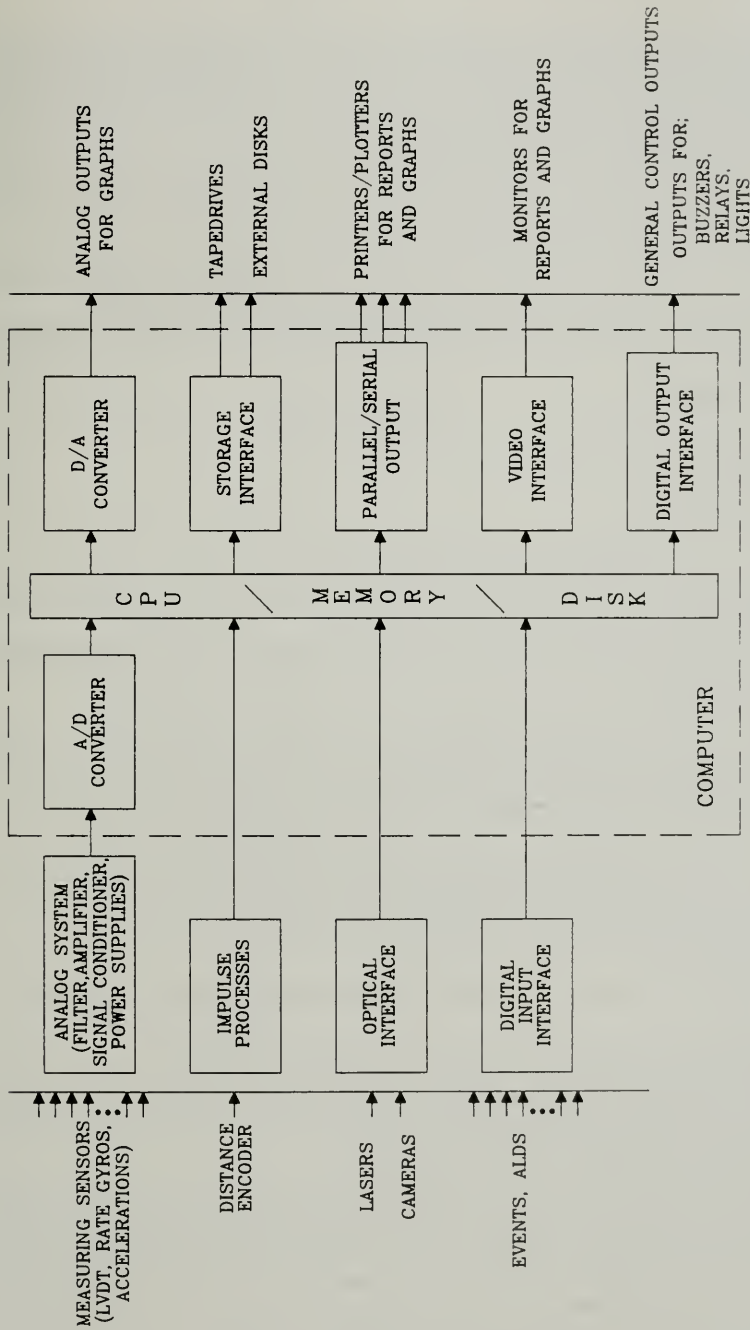


Fig. 2.1 Measuring Vehicle Hardware Block Diagram

Printer/Plotter: This device provides hard copy results of a measuring test. On most geometry measuring vehicles, the defects, their location and a graph represent the measured geometry outputs.

Monitor: This device displays operational commands and raw, calculated or analyzed data, and allows intercommunication with the Central Processing Unit.

Mass Storage: These devices store the raw, calculated or analyzed data on some type of medium like tape, hard disk or static ram memory. By storing the data, a playback of a test run can be performed.

Central Processing Unit: This device is the center of the system, controlling all external peripherals and performing many hundreds of thousands of computations per second.

Track Geometry Parameters: The most common geometry parameters measured by most of the geometry vehicles are:

- (1) Alignment
- (2) Longitudinal Profile
- (3) Gage
- (4) Superelevation
- (5) Parameters calculated from these measurements

Geometry vehicles can be additionally equipped with measuring devices for third (power) rails, catenary wire parameters or clearance measurements.

2.2 RECOMMENDED MINIMUM PERFORMANCE GUIDELINE FOR RAIL TESTING

2.2.1 Introduction

Rail testing must be performed both reliably and economically. On the one hand the rail flaw detection system, comprising both test car and its operator, must strive to correctly identify all rail defects representing a significant risk of rail failure. On the other hand, this must be done at a testing speed that is compatible with train operations and at a price that is commensurate with the service.

100% accuracy in testing is not within the capabilities of current equipment. Nor is it possible to provide near real time quality control feedback to the operator. Given the current state of the art, the risk of rail failure is best controlled with a three-step approach. This consists of:

1. Assessment and calibration of test cars against standard test specimens in a controlled environment.
2. Regular assessment of the performance of rail test cars and operators in regular testing service.
3. Adjustment of rail testing cycles to account for reliability of testing.

Before a correct evaluation of the capabilities of a rail test car can be made, it is first necessary to have a baseline of comparison. Initial calibration of testing equipment is best performed by having test cars run over a test section of rails having known defects.

2.2.2 Performance Guideline for Regular Testing

It is recommended that a Performance Guideline be decided upon to ensure that rail test contractors or the Railway's own operators understand the performance expected of them under day-to-day operations. The Performance Guideline should specify the minimum acceptable performance in terms of the number of valid defects in track that are not reported or otherwise missed. Table 1 presents a sample Performance Guideline. It tabulates the percentage of actual in-track defects that can be expected to be located in a single test by a test car maintained in reasonable condition and operated by an experienced operator in service over a typical mix of track conditions.

If a test car and its operator performs to a standard that exceeds the Performance Guideline of Table 1, the Railway can be satisfied that testing frequencies common in the industry will provide acceptable management of risk. If the Railway measures performance that is inferior to this guideline, the equipment and/or operator should be scrutinized. If it is decided to retain the testing system in question, testing intervals should be tightened to achieve the same net risk of service failures.

The guideline could therefore be used as the basis of an agreement between the rail testing operator and the Railway as to minimum acceptable performance. A Railway might choose to incorporate Table 1, or its own variation thereof into a contract, so that inferior performance by a contractor would constitute violation of contract terms.

The purpose of the Performance Guideline of Table 1 is therefore to provide a means for a Railway that does not possess a similar standard to recognize when test performance has fallen to a level that need not be accepted.

2.2.3 Measuring Against the Performance Guidelines

The Performance Guideline is based upon two performance measures which must be balanced. These are:

1. Missed Detection of a Defect

- a defect of detectable size and type was not found and/or not reported.

Typically this would be seen as a rail service failure within an unacceptable short interval which, upon examination, was estimated to have been of detectable size at time of testing.

2. False Alarms

- a defect was reported that did not exist or did not represent a risk of rail failure sufficient to merit a rail plug.

This would typically be found in a program of breaking open a sample of rails marked by a rail test car. Examples of “false alarms” would be a rail with shatter cracks that had been interpreted as a transverse defect or a poor rail end buildup by welding that was interpreted as a horizontal split head.

In a regular test environment, precise verification of the performance of a rail testing system against these statistics is not possible, as it requires a knowledge of how many rail defects went undetected. Nonetheless, estimates can be made through parallel testing with two or more different cars and by reviewing ratios of service to detected rail failures.

2.2.4 Verification of Reliability Ratio for Missed Defects

Verification through parallel testing

As there is no absolute method of verifying rail test reliability, some railways incur the additional cost of parallel, or redundant, testing over substantial mileages. This would involve deliberately scheduling two or more test cars over the same length of track, without changing out rails until inspected by both test cars. The test cars could represent two different operators of the same basic equipment, or they could be different systems or contractors. When a defect is detected by the lead car, its location is referenced but any marking is on the underside of the rail head so that it cannot be seen by the following car. Each car alternates as the lead car to avoid biasing the results. All defects detected by either car are then examined with hand probes. If there is any further doubt as to the presence of a defect, the rail specimen is broken open for examination.

After elimination of falsely-reported defects from the sample, the total of all defects found by either car is used as an estimate of N , the population of defects of detectable size within the test segment, i.e.

$$\begin{aligned} N &= \text{verified defects found by Car A} \\ &+ \text{verified defects found by Car B} \\ &- \text{common defects found by both Cars A and B} \end{aligned}$$

The overall Reliability Ratio, R for each test car is then calculated as

$$R = \frac{\% \text{ of all valid defects that were found by Car A}}{\frac{\text{No. of verified defects found by Car A}}{N}}$$

If a sufficient number of defects are found of a particular type and size, the Reliability Ratio can also be specific to the defect class, enabling direct comparison with the column in Table 1 entitled: "% of such defects properly indicated as flaws in any single test."

Verification from service failures and visual defects ratios

In the case of medium to large defects, test reliability can also be inferred from the ratio of service to detected failures. For example, in a territory tested by a particular test car, a railway may have reported 15 service failures from large transverse defects within a given year. This is equivalent to "missed detections." The total number of detected TD's in the same territory over the same year, say 500, can be assumed to represent the remainder of the population of defects of detectable size within the track in the year. Both the detected defects and the inferred total defect population may be adjusted to account for false alarms if an adjustment factor can be inferred from rail breaking tests. In the following example, it is assumed that typically 15% of transverse defects reported are not valid defects.

Therefore, in this example, the Reliability Ratio for large transverse defects, R_{TDL} , would be:

$$R_{TDL} = \frac{500 (1-0.15)}{500 (1-0.15) + 15} = 97\%$$

which would not meet the performance Guideline for a Category I track, which would be 98% for Transverse Defects of size 41%-80% of head area.

To produce a fair tally of "misses," service/visual defects must have occurred within a reasonable interval after testing. The interval decided upon must account for the possible growth of the defect after the test. For example, one railway uses the assumption that any service failure should have been classified as "LARGE" if it has failed within 5 MGT of the test, "MEDIUM TO LARGE" if it has failed within 10 MGT of the test and "SMALL TO LARGE" if it has failed within 20 MGT of the test. Failures that have occurred more than 20 MGT from the test are not counted as misses.

False Reporting of Defects

The standard for false reporting (false alarms) can be measured by selecting a sample of rails that have been marked as defective in the field and have been removed from track. The defect can usually be verified on site by hand held ultrasonic probes. It is useful to have the test car operator present, or the contractor's representative if it is a contract service. If there is any doubt as to the size or the presence of the defect, the rail sample can be shipped to a location where it can be broken open for examination.

In this way, a tally can be made of the percent of rails that did not contain a defect, or contained a flaw that would be considered to be of a type or size that had been previously agreed among all parties to constitute no risk of failure.

Table 1.
Recommended Minimum Performance Guideline for Rail Testing

Defect Type	Size (Length or % of head area fractured)	Reliability Ratio (% of such defects properly indicated as flaws in any single test)	
		Category I	Category II
1. Transverse Defects in the Rail Head	5 - 10%	65%	55%
e.g. transverse fissure	10 - 20%	85%	75%
compound fissure	21 - 40%	90%	85%
engine burn fracture	41 - 80%	98%	95%
welded burn fracture	81 - 100%	99%	99%
2. Detail fracture from shelling or Head Check	10 - 20%	65%	55%
	21 - 40%	85%	75%
	41 - 80%	95%	85%
	81 - 100%	98%	95%
3. Defective welds - Plant Welds (Head)	3 - 5%	65%	—
	5 - 10%	75%	65%
	11 - 20%	85%	75%
	21 - 40%	90%	85%
	41 - 80%	95%	95%
	81 - 100%	99%	99%
- Plant Welds (Web)	1/2 - 1"	75%	65%
	1 - 2"	95%	90%
	more than 2"	99%	95%
- Field Welds (Head)	5 - 10%	75%	65%
	11 - 20%	80%	70%
	21 - 40%	85%	80%
	41 - 80%	95%	90%
	81 - 100%	99%	95%
- Field Welds (Web)	1/2 - 1"	75%	65%
	1 - 2"	90%	85%
	more than 2"	99%	95%
4. Longitudinal Defects in the Rail Head	2 - 4 in. long	80%	70%
e.g. horizontal split head	4 - 36 in.	95%	95%
vertical split head	more than 36 in.	99%	99%
5. Web Defects* e.g. head and web separation split web	2 - 4 in.	95%	90%
	more than 4 in.	98%	95%
6. Piped rail	more than 8 in.	85%	—
	any size with non- vertical orientation, evidence of bulged web or progression into weld	85%	75%

Cont'd

Table 1. (Cont'd)

Recommended Minimum Performance Guideline for Rail Testing

		Category I	Category II
7. Web Defects in	1/2 - 1"	75%	65%
Joint Area*	1 - 2 in.	75%	65%
e.g. bolt hole crack	2 - 4 in.	90%	85%
head and web separation	more than 4 in.	99%	99%

*defects must have progressed more than halfway through the web.

In all testing, not more than 5% of defects indicated can be "false alarms," i.e. with no perceptible rail defect as verified statistically by rail breaking tests.

No more than 25% of detected defects may be classified in the wrong defect size class.

CATEGORY I track includes all main track with annual tonnage equal to or exceeding 3 MGT/yr., or with trains speeds equal to or exceeding 40 mph, or track which carries passenger trains or hazardous commodities.

CATEGORY II track includes all sidings and track with annual tonnage less than 3 MGT/yr. and train speeds less than 40 mph unless carrying passenger trains or hazardous commodities.

Proposed 1992 Manual Revisions To Chapter 3—Ties and Wood Preservation

A recommended industrial grade tie specification has been developed and is proposed to be added as Part 12 to Chapter 3. The proposed specifications are:

Part 12

Specifications for Timber Industrial Grade Cross Ties

12.1 MATERIAL

12.1.1 Kinds of Wood

Before manufacturing ties, producers shall ascertain which of the following kinds of wood suitable for cross ties will be accepted:

Ashes	Elms	Larches	Poplars
Beech	Firs (true)	Locusts	Redwoods
Birches	Gums	Maples	Sassafras
Catalpas	Hackberries	Mulberries	Spruces
Cherries	Hemlocks	Oaks	Sycamores
Douglas Fir	Hickories	Pines	Walnuts

12.2 GENERAL

All procedures regarding quality, manufacture, inspection, shipment, and delivery will comply fully with those specified for grade cross ties in Part 1 unless excepted by Part 12.

12.3 CLASSIFICATION AND DESIGN

The following sizes, lengths, minimum faces and tolerances are allowed:

Grade	Dimensions	Minimum Faces Allowed
6" IG	6" x 8" x 8'0"/8'6"	6" face on top or bottom
7" IG	7" x 8" x 8'0"/8'6"	6" face on top or bottom
7" IG	7" x 9" x 8'0"/8'6"	6" face on top or bottom

The above minimum face requirements apply to the rail-bearing areas, which are the areas between 20" and 40" from the middle of the industrial grade crosstie. Outside the rail-bearing areas, wane will be limited to half the face width on the top and bottom of the tie. The grade of each tie shall be determined at the point of most wane, on the top or bottom, within the rail-bearing areas. (The top is defined as the horizontal face farthest from the heartwood or pith center).

Dry or treated ties may be 1" narrower or 1/2" thinner than the specified sizes. Thickness and width may not vary more than 1" from end to end. The tie body may be out of square by no more than 1" throughout the length. Tie length may vary from +1" to -3" for the length specified.

Proposed 1992 Manual Revisions To Chapter 4 - Rail

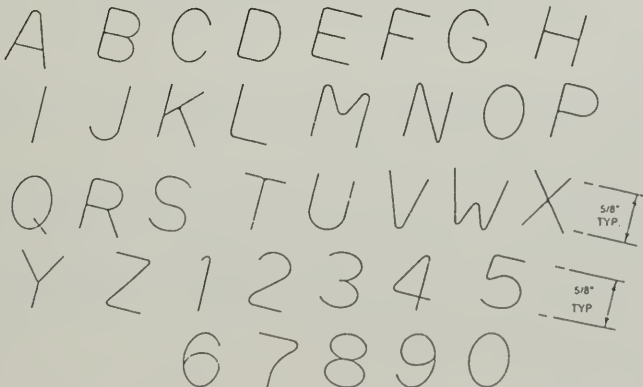
Proposed revisions to Chapter 4 include for Part 2 - Specifications new requirements in Article 6.2.5 for rail stamping and in Article 9.2.4 rewording of the last sentence. Specifically the changes are as follows:

Article 9.2.4. Revise last sentence of current specification to:

A rust inhibitor may be applied to the etched face at the request of the purchaser.

Article 6.2.5 Revise requirements in this article to:

The 5/8" stamped characters shall have a flat or radius face (0.40" to 0.060" wide) with bevels on each side so as not to produce metallurgical stress risers. The letters and numbers shall be on a 10° angle from vertical and shall have rounded corners. The stamping shall be 0.020" and 0.060" in depth along the center of the web. The design shall be as shown in Figure 6.1.



DESIGN OF SPECIAL LETTERS AND NUMBERS ON A 10° ANGLE
FOR RAIL STAMPS, NO SHARP CORNERS

Figure 6.1

Proposed 1992 Manual Revisions To Chapter 5—Track

Proposed revisions to Chapter 5 include a retitling and rewrite of “Lubrication of Rail Curves” in Part 5 to “Wayside Lubrication of Rail on Curves”, and a total rewrite of Part 1—Tie Plates.

New recommendations contained in the wayside lubrication specifications are discussion on curve units and included central angle methods, which are used in determining lubricator location where there are a series of curves, suggestions that both high and low rails in curves be lubricated, a listing of parameters to be considered in choosing a lubricant and discussion on alternate methods of rail lubrication.

The AREA Tie Plate Specification has been updated to reflect current railroad and steel making practices. The revisions incorporate current cross references, add critical limits and tolerances on chemistry and dimensions, clarify language for product re-testing and add definition of terms. The format of the specification has changed slightly to reflect the technical changes and to improve the readability of the drawings. The list of recommended plate designs have been revised to reflect current practice.

Significant revisions include:

- Inclusion of cross reference to ASTM A67, Specification for Steel Tie Plates, Low-Carbon and High-Carbon-Hot-Worked.
- Addition of requirement to assure freedom from segregation and pipe.
- Increase in the number of test samples for chemical analysis.
- Inclusion of modern test methods.
- Addition of restrictions on sulfur content, removal of restrictions on copper.
- Addition of tolerances on chemical content restrictions.
- Clarifications and additional restrictions on retesting.
- Clarification of allowable dimensional tolerances and addition of other important tolerances.

This specification is proposed to replace the existing specification, Part 1, Tie Plates (dated 1968) in its entirety.

The proposed material for Part 5 and Part 1 respectively is as follows:

Wayside Lubrication of Rail on Curves

- 5-5-10.1.** Lubrication is recommended where there is excessive wear on the rail or noise abatement is desired.
- 5-5-10.2** Lubrication can be accomplished thru the use of train actuated devices which dispense lubricant to passing wheel flanges for rolling distribution or in special cases, manual application of lubricant may be necessary.
- 5-5-10.3** Lubricators should be located and installed in accordance with manufacturer's recommendations. Lubricators should be located prior to entering the body of the curve. Physical characteristics such as crossings, station platforms or other obstructions must then be given consideration. Location of lubricators also depends on whether a single or series of curves is to be protected. For a single curve, the degree of curve determines the need for protection. For a series of curves, the spacing between lubricators is based on tabulating total units by one of the following methods:
- 1) Curve units.
 - 2) Included central angle.

5-5-10.3.1 Curve Units—

One curve unit is one foot of one degree curve. To find the number of curve units in a curve, the length, including spirals, is multiplied by the degree of curve. For example: a five (5) degree curve which is 1,000 ft. long contains 5,000 curve units.

5-5-10.3.2 Included Central Angle—

This is the sum of the central angles of a series of curves. The central angle of a curve is found by multiplying the degree of curvature by the length of curve (in feet) divided by 100. For example: a five (5) degree curve with a length of 2,000 ft. contains one hundred (100) degrees of central angle.

5-5-10.3.3 Locations may be adjusted considering rail wear observations and operating conditions.**5-5-10.4 Grease travel distances may be affected by: grades, tonnage, speed, type of grease, weather, and curvature.****5-5-10.5 Dispersion of grease should be regulated to stay on the gage face of the rail and off the top of the rail.****5-5-10.6 Lubrication of both high and low rails of curves is recommended.****5-5-10.7 Lubricator inspection should be frequent enough to insure proper operation. The curve rail should be examined to determine that coverage is adequate.****5-5-10.8 Track gage should be maintained and checked frequently at lubricator locations to provide good wheel flange/rail contact.****5-5-10.9 Alternative methods of rail lubrication (i.e.: on board locomotive, hyrail) are available. Application of the lubricants should be at a frequency to achieve the objectives of 5-5-10.1.****5-5-10.10 The following characteristics should be considered in choosing a lubricant:**

- Mobility (i.e., carry)
- Retentivity (i.e., durability)
- Lubricity (i.e., friction reduction) and
- Viscosity (i.e., temperature adjusted).

AMERICAN RAILWAY ENGINEERING ASSOCIATION

Part 1

Tie Plates

SECTION I. SPECIFICATIONS FOR STEEL TIE PLATES

1.0 SCOPE

- 1.1 These specifications cover steel tie plates for use in railroad track.
- 1.2 Either low carbon or high carbon steel tie plates may be furnished unless purchaser specifies the chemical composition to be used.
- 1.3 ASTM A67 applies in so far as conflicts do not exist.

2.0 MANUFACTURE

- 2.1 Melting Practice—The steel shall be made by any of the following processes: open-hearth, basic-oxygen, or electric-furnace.
- 2.2 The steel shall be cast by a continuous process, in ingots, or by other methods agreed upon by the purchaser and the manufacturer.
- 2.3 Sufficient discard shall be taken from ingots and blooms rolled from ingots to ensure freedom from injurious segregations and pipe.
- 2.4 Tie plates shall be produced from hot rolled steel sections punched and sheared either hot or cold as appropriate to the chemical composition of the steel being used.

3.0 CHEMICAL COMPOSITION

3.1 Composition:

- 3.1.1 The chemical composition of the tie plate steel, determined as prescribed in 3.2.1, shall be within the limits shown in Table 1, Chemical Analysis.
- 3.1.2 Finished material representing the heat may be product tested. The product analysis shall be within the limits for product analyses specified in Table 1.

3.2 Heat or Cast Analysis:

- 3.2.1 Separate analysis shall be made from test samples representing one of the first three and one of the last three ingots or continuously cast blooms preferably taken during the pouring of the heat. Determinations may be made chemically or spectrographically. Any portion of the heat meeting chemical analysis requirements of Table 1 may be applied. Additionally, any material meeting the product analysis limits shown in Table 1 may be applied after testing such material.
- 3.2.2 The first heat analysis shall be recorded as the official analysis, but the purchaser shall have access to all chemical analysis determinations.
- 3.2.3 Upon request by the purchaser, samples shall be furnished to verify the analysis as determined in 3.2.1.

Table 1. CHEMICAL COMPOSITION

Element	Chemical Analysis		Product Analysis	
	Weight Percent		Weight Percent Allowance Beyond Limits of Specified Chemical Analysis	
	Low Carbon Tie Plates	High Carbon Tie Plates	Under Minimum Limit	Over Maximum Limit
Carbon	0.150 min. to 0.349	0.350 to 0.850	0.040	0.000
Phosphorus	0.050 max	0.050 max	N/A	0.008
Sulfur	0.040 max	0.040 max	N/A	0.008

4.0 BENDING PROPERTIES

- 4.1 Bend Test—Low Carbon Steel**—The bend test specimen specified in Article 5 shall stand being bent cold through 180° around a pin the diameter of which is not greater than the thickness of the specimen without cracking on the outside of the bent portion.
- 4.2 Optional Bend Tests—Low Carbon Steel**—If preferred by the manufacturer the following bend test may be substituted for that described in Article 4.1: A piece of the rolled bar or the finished tie plate shall stand being bent cold through 90° around a pin the diameter of which is not greater than the thickness of the section where bent, without cracking on the outside of the bent portion. The term “thickness” includes vertical height of ribs and shoulder where they are transverse to direction of pin.
- 4.3 Bend Test—High Carbon Steel**—The bend test specimen specified in Article 5 shall stand being bent cold through 30° around a pin the diameter of which is not greater than three times the thickness of the specimen without cracking on the outside of the bent portion.
- 4.4 Optional Bend Test—High Carbon Steel**—If preferred by the manufacturer, the following bend test may be substituted for that described in Article 4.3: A piece of the rolled bar or the finished tie plate which may be bent in either direction shall stand being bent cold through 30° around a pin the diameter of which is not greater than three times the thickness of the section where bent, without cracking on the outside of the bent portion. The term “thickness” includes vertical height of ribs and shoulder where they are transverse to direction of pin.

5.0 TEST SPECIMENS

- 5.1** Bend test specimens for sections 4.1 or 4.3 shall be taken longitudinally with the direction of rolling from the finished tie plates, or from the rolled bars. They shall be rectangular in section, not less than 1/2 inch in width between the planed sides, and shall have two faces as rolled. They shall be free from ribs or projections. Where the design of the tie plates is such that the specimen cannot be taken between the ribs or projections, these ribs or projections shall, in preparing the specimen, be planed off even with the main surface of the tie plate.

6.0 NUMBER OF TESTS

- 6.1** One bend test shall be made from each heat of open-hearth, electric-furnace or basic-oxygen steel, or from each 25 tons where heats are not identified.
- 6.2** If any test specimen shows defective machining or surface flaws, it may be discarded and another specimen substituted.

7.0 RETESTS

- 7.1 High carbon steel tie plates represented by bend tests failing to meet the requirements prescribed in Article 4.3 or 4.4 may be reannealed and resubmitted. If tie plates fail to meet the second test they shall be rejected.

8.0 FINISH AND PERMISSIBLE VARIATION IN DIMENSIONS

The tie plates shall be smoothly rolled and free from injurious warp and other imperfections in surface, and projecting fins of metal caused by shearing and punching.

The tie plate shall conform to the dimensions specified by the purchaser, subject to the following permissible variations:

		Inches (thousandths)	
		Plus	Minus
8.1	Tie plates with shoulder parallel to the direction of rolling.		
8.1.1	Variation from design thickness	0.030	0.030
8.1.2	Variation from design length (rolled width)	0.125	0.125
8.1.3	Variation from design width (sheared length)	0.188	0.188
8.1.4	Variation from design shoulder height	0.015	0.030
8.1.5	Variation from design rail seat width (Applies to double shoulder plates only)	0.063	0.000
8.2	Maximum height of shear drag or fins.		
8.2.1	At edge of plate	0.063	0.063
8.2.2	At spike holes	0.063	0.063
8.3	Spike Holes		
8.3.1	Variation from design size	0.030	0.030
8.3.2	Variation from design location	0.030	0.030
8.3.3	Skewness of holes—horizontally	0.030	0.030
8.3.4	Sides of spike holes must allow track spikes to be driven vertically.		

Notes concerning spike holes:

Spike holes are typically punched from the bottom of the plates.

Measurement for size and location should be determined from the punch entering surface.

Measurement of the hole location should be in relationship of the spike holes to each other.

Measurement of the skewness of spike holes should be in relationship to the design location of the rail base for line holes and to the sheared edge for hold down holes.

The following limits on spike hole punching normally apply:

Holes are not punched closer than 1-5/8" inches center to center.

Outer edge of any hole is not closer than 1/2 inch to the rolled edge for plates up to 3/8 inch in end thickness; or closer than 5/8 inch to the rolled edge for plates greater than 3/8 inch up to 1/2 inch in end thickness.

Outer edge of any hole is not closer than 1 inch to the sheared edge.

8.4 Flatness. Concavity or convexity measured with an appropriate gage over the width, length and diagonals with the effect of shear edge deformation disregarded.

8.4.1	Rail Seat	0.025	0.025
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8.4.2	Bottom of Plate	0.060	0.060
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(Does not apply to ribbed tie plates)

8.5 Rail Cant. The rail seat shall provide for cant of 1:40, plus or minus 5, toward center line of track unless otherwise specified.

8.6 Tie plates shall be accepted on the basis of actual weight as applied to the entire order, except that any weight supplied in excess of 3% over the weight calculated from the specified dimensions shall be the responsibility of the manufacturer.

9.0 MARKING

9.1 The tie plate will be marked with 3/8" minimum height raised letters and figures when the section is rolled. The marking shall be on the top of the plate on the field side shoulder. Each finished tie plate will contain a portion of the marking. The marking will contain:

Tie Plate Designation—AREA Tie Plate Plan Number

Name or Brand of Manufacturer

Year of Manufacture: Last two digits of year if space limitation precludes use of four digits.

HW: If tie plate is made of high carbon steel and hot worked. Low carbon steel plates are not marked.

10.0 INSPECTION

10.1 The inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed that concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

11.0 REJECTION

11.1 Material failing to meet the requirements of these specifications will be rejected.

11.2 Material that shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

SECTION 2. DEFINITIONS

Tie Plate.

A part of the track structure placed under the rail to distribute the wheel load to the tie, cant the rail to the desired angle, assist in maintaining the track to gage and protect the tie. The tie plate has a rail seat, either flat or canted, either a single or double shoulder parallel to the rail it supports, and is punched with holes for spikes or other fasteners. The bottom of the tie plate is usually flat, but ribbed or other designs may be used.

Length.

Overall dimension of the plate at right angles to the rail it supports. Tie plates of different length can be used with given rail section with the length chosen based on the traffic density of the track on which it is to be used.

Width.

Overall dimension of the plate parallel to the rail it supports. Tie plates are generally from seven to eight inches wide.

Rolled Width.	The dimension of the finished section as it leaves the rolls and is equal to the length of the tie plate.
Sheared Length.	The dimension to which the finished section is cut and is equal to the width of the tie plate.
Gage Side.	End of tie plate designed to be located closest to the centerline of track.
Field Side.	End of tie plate designed to be located on the opposite side of the rail from the centerline of track.
Rail Seat.	The portion of the tie plate that supports the rail.
Rail Seat Cant.	Tie plates are generally rolled with the rail seat not parallel to the base of the plate so that the rail head is tilted toward the centerline of track to help offset lateral thrust and provide better wheel bearing on the rail head. The AREA recommended cant is a ratio of 1:40.
Shoulder.	A ridge parallel to the rail designed to assist in holding the rail in position. The height of the shoulder is about equal to the thickness of the edge of the rail base. If a plate has a "Single Shoulder," the shoulder is located on the field side of the rail seat to resist the outward thrust of the rail. A "Double Shoulder" plate has an additional shoulder on the gage side of the rail seat. Single shoulder plates may accommodate a desired rail section by adjusting the punching of the spike holes on the gage side to match the width of the rail base. Double shoulder plates are limited to a single rail base width.
Eccentricity.	The distance from the shoulder to the edge of the tie plate at right angles to the shoulder is larger on the field side than the gage side to compensate for the greater tendency of the field end to cut into the tie. The horizontal distance from middle of the rail seat to middle of the tie plate is the eccentricity.
Line Holes.	Located at the edge of the rail seat, these holes allow the spikes to contact the edge of the rail base.
Hold Down Holes.	Located on the plate away from the rail seat, these holes do not allow spikes to contact the edge of the rail base. Also called "Anchor Spike Holes."

DESIGN OF TIE PLATES FOR USE WITH
AREA RAIL SECTIONS

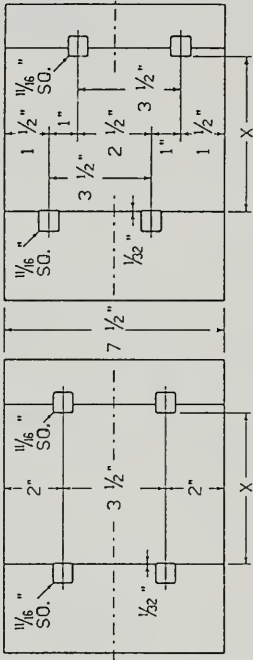
PLAN NUMBER	LENGTH
1	10 INCH FOR USE WITH RAIL HAVING A $5 \frac{1}{8}$ INCH BASE
2	11 INCH FOR USE WITH RAIL HAVING A $5 \frac{1}{8}$ OR $5 \frac{3}{8}$ INCH BASE
3	12 INCH FOR USE WITH RAIL HAVING A $5 \frac{3}{8}$ INCH BASE
6	12 INCH FOR USE WITH RAIL HAVING A $5 \frac{1}{2}$ INCH BASE
7	13 INCH FOR USE WITH RAIL HAVING A $5 \frac{1}{2}$ INCH BASE
8	14 INCH FOR USE WITH RAIL HAVING A $5 \frac{1}{2}$ INCH BASE
11	13 INCH FOR USE WITH RAIL HAVING A 6 INCH BASE
12	14 INCH FOR USE WITH RAIL HAVING A 6 INCH BASE
13	14 $\frac{3}{4}$ INCH FOR USE WITH RAIL HAVING A 6 INCH BASE
20	15 INCH FOR USE WITH RAIL HAVING A $5 \frac{1}{2}$ INCH BASE
21	16 INCH FOR USE WITH RAIL HAVING A 6 INCH BASE
22	18 INCH FOR USE WITH RAIL HAVING A 6 INCH BASE

RAIL		PLATE	
AREA RAIL SECTIONS	BASE WIDTHS	PLAN NUMBER	LENGTH INCHES
140RE, 136RE, 133RE, 132RE	6 INCH	22	18
		21	15
		13	14 $\frac{3}{4}$
		12	14
		11	13
119RE, 115RE	$5 \frac{1}{2}$ INCH	20	15
		8	14
		7	13
		6	12
100RE	$5 \frac{3}{8}$ INCH	3	12
		2	11
90RA- A	$5 \frac{1}{8}$ INCH	2	11
		1	10

TIE PLATES ARE DOUBLE SHOULDER EXCEPT FOR PLAN NUMBER 1 AND 2 WHICH ARE SINGLE SHOULDER.

ALL TIE PLATE SECTIONS CANTED 1 : 40.

ALL TIE PLATE SECTIONS HAVE INCLINED ENDS.

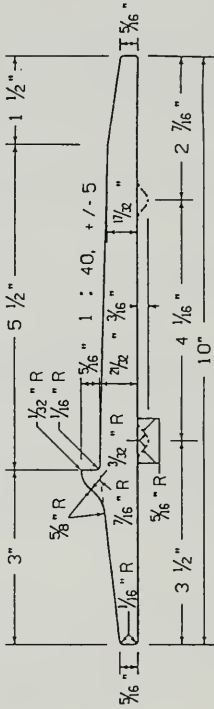


PUNCHING A - 4 SPIKE HOLES PUNCHING B - 4 SPIKE HOLES

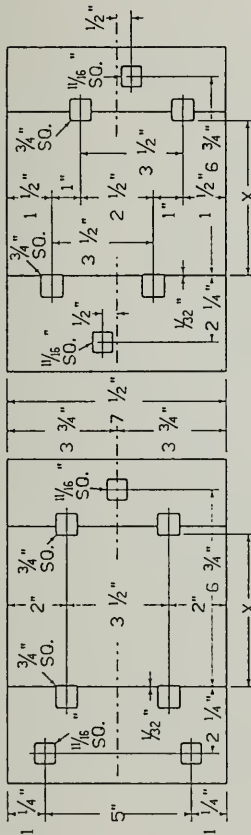
X = NOMINAL WIDTH OF BASE OF RAILS WITH WHICH TIE PLATE IS TO BE USED.

FOR USE WITH 3/16" TRACK SPIKES.
ALL SQUARE SPIKE HOLES WILL HAVE 1/16" FILLETS IN CORNERS.
WHEN SPECIFIED -
SUPPLY SECTION WITH RIBS ON BOTTOM OF PLATE.
FURNISH WITH 3/4" SQUARE HOLES IF 5/8" TRACK SPIKES ARE TO BE USED.

ESTIMATED WEIGHTS IN POUNDS	
PER FOOT	18.60
PER 7 1/2"	11.63
PUNCHED	
4 HOLES	11.28
ADD FOR RIBS	
PER FOOT	0.34
PER 7 1/2"	0.21



PLAN NO. 1 - AREA 10 INCH TIE PLATE FOR USE WITH RAILS HAVING 4 7/16 TO 5 1/8 INCH RAIL BASE WIDTH.
SIZE AND LOCATION OF SPIKE HOLES TO BE OPTIONAL WITH A MAXIMUM OF EIGHT.

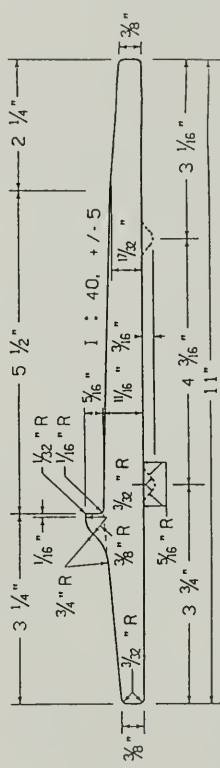


PUNCHING A - 7 SPIKE HOLES
PUNCHING C - 4 LINE SPIKE HOLES
OF PUNCHING A

PUNCHING B - 6 SPIKE HOLES
PUNCHING D - 4 LINE SPIKE HOLES
OF PUNCHING B

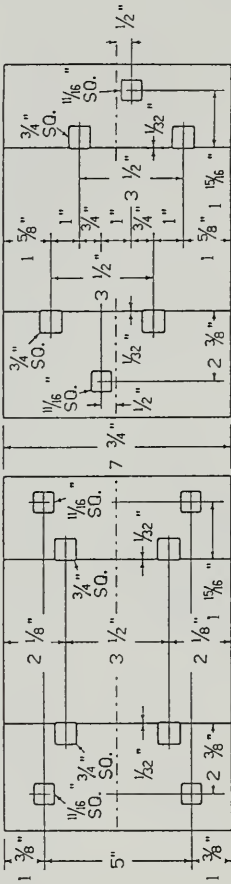
X = NOMINAL WIDTH OF BASE OF RAILS WITH WHICH TIE PLATE IS TO BE USED.

ALL SQUARE SPIKE HOLES WILL HAVE $\frac{1}{16}$ " FILLETS IN CORNERS.
WHEN SPECIFIED.
SUPPLY SECTION WITH RIBS ON BOTTOM OF PLATE.
CENTERLINE DISTANCE BETWEEN HOLD DOWN SPIKE HOLES $4 \frac{1}{2}$ " INSTEAD OF 5".



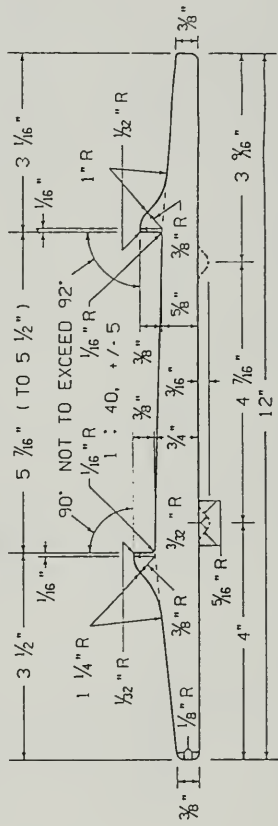
PLAN NO. 2 - AREA 11 INCH TIE PLATE FOR USE WITH RAILS HAVING $5 \frac{1}{8}$ TO $5 \frac{1}{2}$ INCH RAIL BASE WIDTH.
SIZE AND LOCATION OF SPIKE HOLES TO BE OPTIONAL WITH A MAXIMUM OF EIGHT.

ESTIMATED WEIGHTS IN POUNDS	
PER FOOT	21.58
PER 7 $\frac{1}{2}$ "	13.49
PUNCHED	
7 HOLES	12.87
6 HOLES	12.93
4 HOLES	13.05
ADD FOR RIBS	
PER FOOT	0.34
PER 7 $\frac{1}{2}$ "	0.21



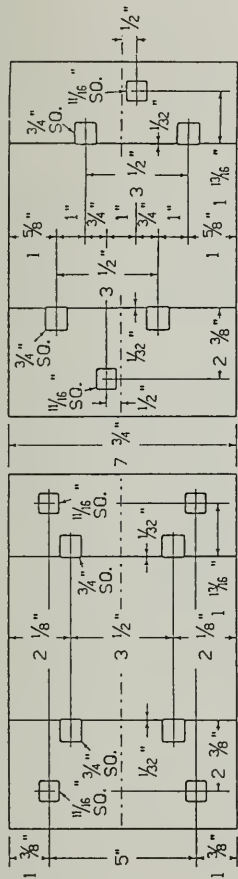
PUNCHING A - 8 SPIKE HOLES
PUNCHING B - 6 SPIKE HOLES
PUNCHING C - 4 LINE SPIKE HOLES
PUNCHING D - 4 LINE SPIKE HOLES

ALL SQUARE SPIKE HOLES WILL HAVE 1/16" FILLETS IN CORNERS.
WHEN SPECIFIED -
SUPPLY SECTION WITH RIBS ON BOTTOM OF PLATE.
CENTERLINE DISTANCE BETWEEN HOLD DOWN SPIKE HOLES 4 1/2" INSTEAD OF 5".
ROUND HOLES MAY BE SUBSTITUTED FOR SQUARE HOLD DOWN SPIKE HOLES.



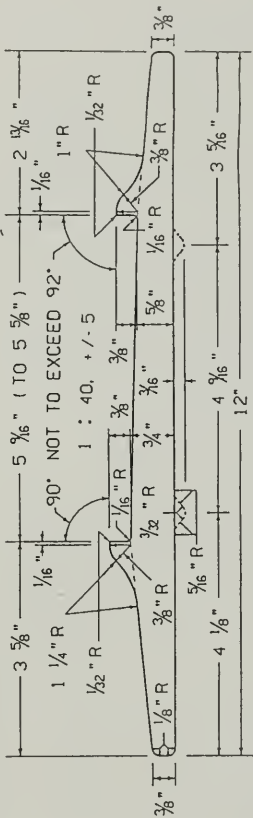
PLAN NO. 3 - AREA 12 INCH TIE PLATE FOR 5 3/8 INCH RAIL BASE WIDTH.
SIZE AND LOCATION OF SPIKE HOLES TO BE OPTIONAL WITH A MAXIMUM OF EIGHT.

ESTIMATED WEIGHTS IN POUNDS	
PER FOOT	25.84
PER 7 3/4"	16.69
PUNCHED	
8 HOLES	15.86
6 HOLES	15.99
4 HOLES	16.12
ADD FOR RIBS	
PER FOOT	0.34
PER 7 3/4"	0.22



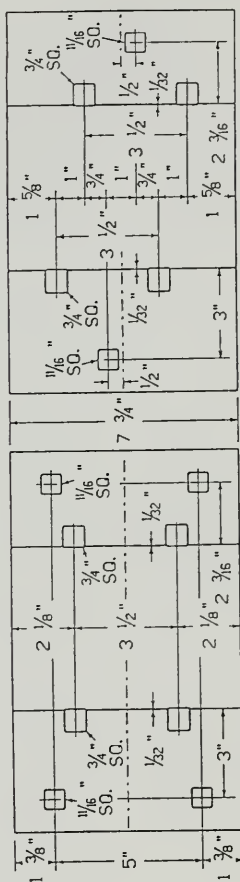
PUNCHING A - 8 SPIKE HOLES
PUNCHING C - 4 LINE SPIKE HOLES
PUNCHING B - 6 SPIKE HOLES
PUNCHING D - 4 LINE SPIKE HOLES
OF PUNCHING A
OF PUNCHING B

ALL SQUARE SPIKE HOLES WILL HAVE 1/16" FILLETS IN CORNERS.
WHEN SPECIFIED -
SUPPLY SECTION WITH RIBS ON BOTTOM OF PLATE.
CENTERLINE DISTANCE BETWEEN HOLD DOWN SPIKE HOLES 4 1/2" INSTEAD OF 5".
ROUND HOLES MAY BE SUBSTITUTED FOR SQUARE HOLD DOWN SPIKE HOLES.



PLAN NO. 6 - AREA 12 INCH TIE PLATE FOR 5 1/2 INCH RAIL BASE WIDTH.
SIZE AND LOCATION OF SPIKE HOLES TO BE OPTIONAL WITH A MAXIMUM OF EIGHT.

ESTIMATED WEIGHTS IN POUNDS	
PER FOOT	25.95
PER 7 3/4"	16.76
PUNCHED	
8 HOLES	15.94
6 HOLES	16.06
4 HOLES	16.19
ADD FOR RIBS	
PER FOOT	0.34
PER 7 3/4"	0.22



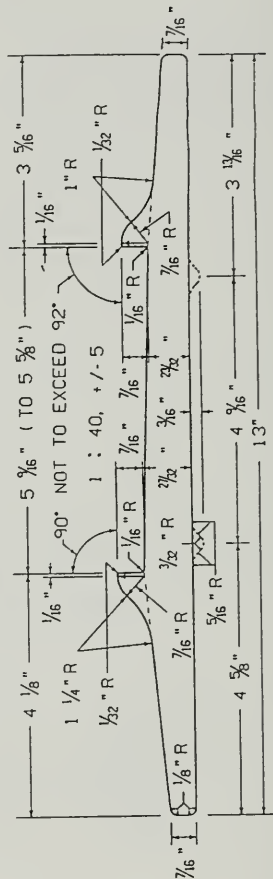
PUNCHING A - 8 SPIKE HOLES
PUNCHING C - 4 LINE SPIKE HOLES
OF PUNCHING A

PUNCHING B - 6 SPIKE HOLES
PUNCHING D - 4 LINE SPIKE HOLES
OF PUNCHING B

ALL SQUARE SPIKE HOLES WILL HAVE $\frac{1}{16}$ " FILLETS IN CORNERS.

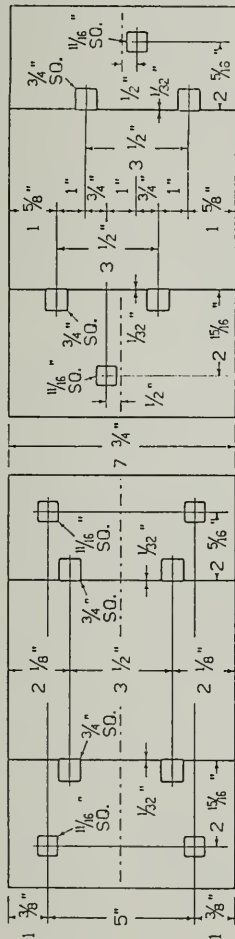
WHEN SPECIFIED -

SUPPLY SECTION WITH RIBS ON BOTTOM OF PLATE.
CENTERLINE DISTANCE BETWEEN HOLD DOWN SPIKE HOLES $4\frac{1}{2}$ " INSTEAD OF 5".
ROUND HOLES MAY BE SUBSTITUTED FOR SQUARE HOLD DOWN SPIKE HOLES.



PLAN NO. 7 - AREA 13 INCH TIE PLATE FOR $5\frac{1}{2}$ INCH RAIL BASE WIDTH.
SIZE AND LOCATION OF SPIKE HOLES TO BE OPTIONAL WITH A MAXIMUM OF EIGHT.

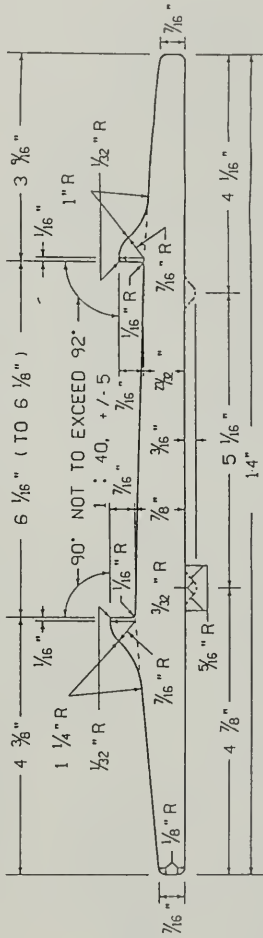
ESTIMATED WEIGHTS IN POUNDS	
PER FOOT	31.84
PER $7\frac{3}{4}$ "	20.56
PUNCHED	
8 HOLES	19.60
6 HOLES	19.74
4 HOLES	19.89
ADD FOR RIBS	
PER FOOT	0.34
PER $7\frac{3}{4}$ "	0.22



PUNCHING A - 8 SPIKE HOLES
PUNCHING C - 4 LINE SPIKE HOLES
OF PUNCHING A

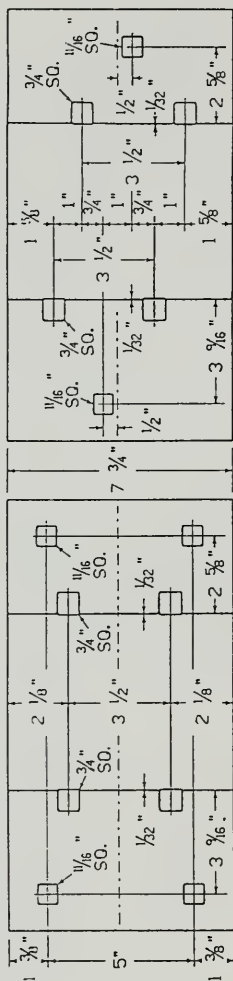
PUNCHING B - 6 SPIKE HOLES
PUNCHING D - 4 LINE SPIKE HOLES
OF PUNCHING B

ALL SQUARE SPIKE HOLES WILL HAVE 1/16" FILLETS IN CORNERS.
WHEN SPECIFIED .
SUPPLY SECTION WITH RIBS ON BOTTOM OF PLATE.
CENTERLINE DISTANCE BETWEEN HOLD DOWN SPIKE HOLES 4 1/2" INSTEAD OF 5".
ROUND HOLES MAY BE SUBSTITUTED FOR SQUARE HOLD DOWN SPIKE HOLES.



PLAN NO. 12 - AREA 14 INCH TIE PLATE FOR 6 INCH RAIL BASE WIDTH.
SIZE AND LOCATION OF SPIKE HOLES TO BE OPTIONAL WITH A MAXIMUM OF EIGHT.

ESTIMATED WEIGHTS IN POUNDS	
PER FOOT	34.77
PER 7 3/4"	22.45
PUNCHED	
8 HOLES	21.47
6 HOLES	21.62
4 HOLES	21.77
ADD FOR RIBS	
PER FOOT	0.34
PER 7 3/4"	0.22



PUNCHING B - 6 SPIKE HOLES
PUNCHING D - 4 LINE SPIKE HOLES
OF PUNCHING B

PUNCHING A - 8 SPIKE HOLES
PUNCHING C - 4 LINE SPIKE HOLES
OF PUNCHING A

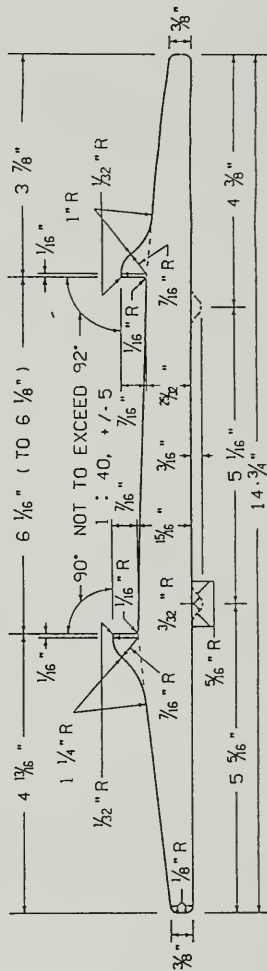
ALL SQUARE SPIKE HOLES WILL HAVE $\frac{1}{16}$ " FILLETS IN CORNERS.

WHEN SPECIFIED -

SUPPLY SECTION WITH RIBS ON BOTTOM OF PLATE.

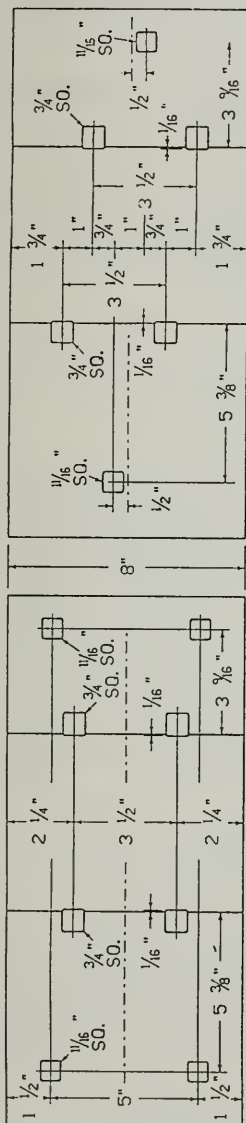
CENTERLINE DISTANCE BETWEEN HOLD DOWN SPIKE HOLES 4 1/2" INSTEAD OF 5".

ROUND HOLES MAY BE SUBSTITUTED FOR SQUARE HOLD DOWN SPIKE HOLES.



PLAN NO. 13 - AREA 14 3/4 INCH TIE PLATE FOR 6 INCH RAIL BASE WIDTH.

SIZE AND LOCATION OF SPIKE HOLES TO BE OPTIONAL WITH A MAXIMUM OF EIGHT.



PUNCHING B - 6 SPIKE HOLES
PUNCHING D - 4 LINE SPIKE HOLES
OF PUNCHING B

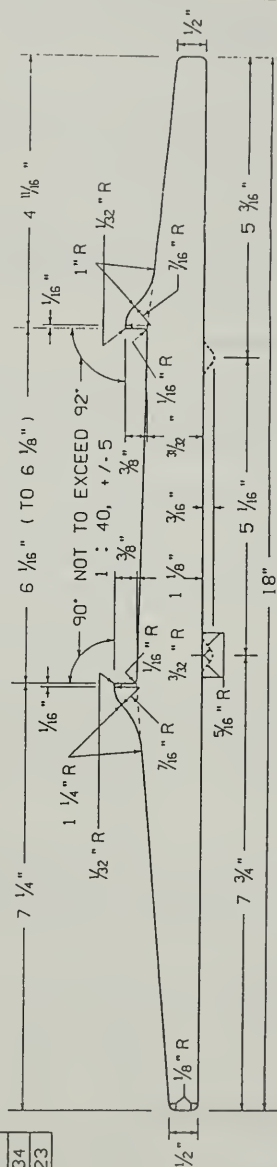
PUNCHING B - 6 SPIKE HOLES
PUNCHING D - 4 LINE SPIKE H
OF PUNCH

ALL SQUARE SPIKE HOLES WILL HAVE $\frac{1}{16}$ " FILLETS IN CORNERS.

WHEN SPECIFIED .

SUPPLY SECTION WITH RIBS ON BOTTOM OF PLATE.

CENTERLINE DISTANCE BETWEEN HOLD DOWN SPIKE HOLES 4 1/2" INSTEAD OF 5".
 AROUND HOLES MAY BE SUBSTITUTED FOR SQUARE HOLD DOWN SPIKE HOLES.



PLAN NO. 22 - 18 INCH TIE PLATE FOR 6 INCH RAIL BASE WIDTH.

SIZE AND LOCATION OF SPIKE HOLES TO BE OPTIONAL WITH A MAXIMUM OF EIGHT.

ESTIMATED WEIGHTS IN POUNDS	
PER FOOT	54.53
PER 8"	36.36
PUNCHED	
8 HOLES	35.21
6 HOLES	35.38
4 HOLES	35.55
ADD FOR RIBS	
PER FOOT	0.34
PER 8"	0.23

Proposed 1992 Manual Revisions To Chapter 8 - Concrete Structures and Foundations

Revisions to Parts 1, 2, 12, 14 and 22 of Chapter 8 are proposed. Details for each Part follow:

PART 1—MATERIALS, TESTS AND CONSTRUCTION REQUIREMENTS

Changes proposed are to replace Sections 1.5, 1.6 and 1.9, Articles 1.2.2, 1.8.4, 1.10.3, 1.10.5, 1.13.9 and 1.17.4, and Subarticle 1.10.4.3 all of which are rewritten and should be replaced in their entirety. For Section 1.17 only the heading is revised. Sections 1.21 and 1.22 are new Sections to be added, and a Commentary and Bibliography is proposed to be added at the end of Part 1. The changes in order of numerical sequence are:

1.2.2 Specifications

The materials used shall conform in physical properties to the AREA Specifications for concrete and reinforced concrete railroad bridges and other structures, and as specified:

1.2.2.1 Portland Cement ASTM C 150

Type I	For use when the special properties specified for any other type are not required.
Type IA	Air-entraining cement for the same uses as Type I, where air-entrainment is desired.
Type II	For general use, especially when moderate sulfate resistance, or moderate heat of hydration is desired.
Type IIA	Air-entraining cement for the same uses as Type II, where air-entrainment is desired.
Type III	For use when high early strength is desired.
Type IIIA	Air-entraining cement for the same use as Type III, where air-entrainment is desired.
Type IV	For use when a low heat of hydration is desired.
Type V	For use when high sulfate resistance is desired.

1.2.2.2 Blended Hydraulic Cements ASTM C 595

PORTLAND BLAST-FURNACE SLAG CEMENT

Type IS	Portland blast-furnace slag cement for use in general concrete construction.
Type IS()	Moderate sulfate resistant (MS), air-entrainment (A), or moderate heat of hydration (MH), or any combination may be specified by adding the appropriate suffixes.

PORTLAND-POZZOLAN CEMENT

Type IP	Portland-Pozzolan cement for use in general concrete construction.
Type IP()	Moderate sulfate resistance (MS), air-entrainment (A), or moderate heat of hydration (MH), or any combination may be specified by adding the appropriate suffixes.
Type P	Portland-pozzolan cement for use in concrete construction where high early strengths are not required.
Type P()	Moderate sulfate resistance (MS), air-entrainment (A), or low heat of hydration (LH), or any combination may be specified by adding the appropriate suffixes.

SLAG CEMENT

Type S Slag cement for use in combination with portland cement in making concrete, and in combination with hydrated lime in making masonry mortar.

Type S() Air-entraining can be specified by adding the suffix (A).

POZZOLAN-MODIFIED PORTLAND CEMENT

Type I(PM) Pozzolan-modified portland cement for use in general concrete construction.

Type I(PM) Moderate sulfate resistance (MS), air-entraining (A), or moderate heat of hydration (MH), or any combination may be specified by adding the appropriate suffixes.

SLAG-MODIFIED PORTLAND CEMENT

Type I(SM) Cement for use in general concrete construction.

Type I(SM)() Moderate sulfate resistance (MS), air-entraining (A), or moderate heat of hydration (MH), or any combination may be specified by adding the appropriate suffixes.

Proper recognition shall be given to the possible effects of slower strength gain and lower heat of hydration on concrete proportioning and concrete construction practices.

Proper recognition shall be given to changes in all properties of concrete if fly ash or other pozzolans are used as admixtures resulting in reduction of the portland cement components in concrete.

1.5 REINFORCEMENT**1.5.1 General**

Reinforcement shall be deformed reinforcement, except that plain bars and plain wire shall be permitted for spirals or tendons, or for dowels at expansion or contraction joints. Reinforcement consisting of structural steel, steel pipe, or steel tubing shall be permitted for composite compression members.

1.5.2 Welding

Welding of reinforcing bars shall be performed as indicated on the plans. All welding of reinforcing bars shall conform to "Structural Welding Code—Reinforcing Steel" (ANSI/AWS D1.4) of the American Welding Society. The ASTM specifications for reinforcing bars, except for ASTM A706, shall be supplemented to require a report of material properties necessary to conform to welding procedures specified in ANSI/AWS D1.4.

If welding of wire to wire, and of wire or welded wire fabric to reinforcing bars or structural steels is to be required on a project, the Engineer shall specify procedures or performance criteria for this welding.

1.5.3 Specifications

1.5.3.1 Reinforcing bars, wire, and welded wire fabric shall conform to one of the following ASTM specifications:

Type	Designation
Deformed and Plain Billet-Steel Bars	A615
Low-Alloy Steel Deformed Bars	A706
Steel Wire, Deformed (wire shall not be smaller than size D4 (.225 inch dia.)	A496

Type (con't)	Designation (con't)
Steel Welded Wire Fabric, Plain	A185
Steel Welded Wire Fabric, Deformed (welded intersections shall not be spaced farther apart than 16 in. in direction of primary flexural reinforcement)	A497
Steel wire, Plain (wire shall not be smaller than size W4 (0.226 inch dia.))	A82

1.5.3.2 Prestressing tendons shall conform to one of the following ASTM specifications:

Type	Designation
Steel Strand, Uncoated Seven-Wire for Prestressed Concrete	A416
Uncoated Stress-Relieved Steel Wire	A421
Uncoated High-Strength Steel Bar	A722

Strands, wire and bars not specifically listed in A416, A421 and A722 may be used provided they conform to minimum requirements of these specifications and do not have properties that make them less satisfactory than those listed in A416, A421, and A722.

1.5.3.3 Structural steel, steel pipe, or tubing shall conform to one of the following ASTM specifications:

Type	Designation
Structural Steel	A36, A242, A441, A572, A588, A709 or (Grade 36, 50 or 50W)
Steel Pipe or Tubing	A53 (Grade B), A500 or A501

1.5.3.4 Coated Reinforcement

Coated reinforcement, when specified or shown on the plans as a corrosion-protection system, shall conform to one of the following ASTM specifications:

Type	Designation
Epoxy-Coated Reinforcing Steel Bars	A775
Epoxy-Coated Steel Wire and Welded Wire Fabric	A884
Zinc-Coated (Galvanized) Steel Bars	A767

For zinc-coated (galvanized) reinforcing bars conforming to ASTM A767, supplementary requirements S1 and S2 shall apply when fabrication after galvanization includes cutting and bending. Supplementary requirement S2 shall apply when fabrication after galvanization includes only bending.

Repair of damaged epoxy coating on reinforcing bars, when required, shall be made with patching material conforming to ASTM A775. Repair shall be done in accordance with the material manufacturer's recommendations.

Repair of damaged epoxy coating on wire or welded wire fabric, when required, shall be made with patching material conforming to ASTM A884. Repair shall be done in accordance with the material manufacturer's recommendations.

Repair of damaged zinc coating on reinforcing bars, when required shall be made with a zinc-rich formulation conforming to ASTM A767. Repair shall be done in accordance with the material manufacturer's recommendations.

Equipment for handling epoxy-coated reinforcing bars shall have protected contact areas. Bundles of coated bars shall be lifted at multiple pickup points to prevent bar-to-bar abrasion from sags in the bundles. Coated bars or bundles of coated bars shall not be dropped or dragged. Coated bars shall be stored on protective cribbing. Coating damage due to handling, shipping, and placing need not be repaired in cases where the damaged area is 0.003 square inch or smaller. The maximum amount of damage including repaired and unrepaired areas shall not exceed 2 percent of the surface area of each bar.

After installation of mechanical connections on epoxy-coated or zinc-coated (galvanized) reinforcing bars, coating damage shall be repaired in accordance with the material manufacturer's recommendations. All parts of mechanical connections used on coated bars, including steel splice sleeves, bolts, and nuts shall be coated with the same material used for repair of coating damage.

After completion of welding for welded splices on epoxy-coated or zinc-coated (galvanized) reinforcing bars, coating damage shall be repaired in accordance with the material manufacturer's recommendations. All welds, and all steel splice members when used to splice bars, shall be coated with the same material used for repair of coating damage.

1.5.4 Bending and Straightening

Reinforcement bars shall only be fabricated in accordance with Article 1.9.2 and Part 2, Article 2.4.2. Field bending and straightening of partially embedded bars shall be done only in accordance with the Plans or as permitted by the Engineer.

1.6 CONCRETE ADMIXTURES

1.6.1 General

Admixtures to be used in concrete shall be subject to prior approval by the Engineer.

An admixture shall be shown capable of maintaining essentially the same composition and performance throughout the work as the product used in establishing concrete proportions in accordance with Section 1.11.

Admixtures containing chloride ions shall not be used unless approved by the Engineer.

Special purpose admixtures may be used, if approved by the Engineer. However, before an admixture can be approved for use, it must be shown that its use will not adversely affect the placement, strength and/or durability of the concrete. Admixtures used in combination may be incompatible and their performance should be verified by prior testing.

1.6.2 Types of Admixtures

1.6.2.1 Air Entraining Agents—ASTM C 260

An admixture that causes entrained air to be incorporated in the concrete or mortar during mixing, by creating a system of minute bubbles of air within the mass, usually to increase its workability and resistance to freeze and/or thaw damage.

1.6.2.2 Accelerating Admixture—ASTM C 494

An admixture that, when added to concrete, mortar or grout, shortens the time of setting, or increases the rate of strength, development, or both.

1.6.2.3 Retarding Admixture—ASTM C 494

An admixture which delays the setting of cement paste, which increases the time required to reach initial and final set or to develop early strength of fresh concrete, mortar, or grout.

1.6.2.4 Water Reducing Admixture—ASTM C 494

An admixture that reduces the quantity of mixing water required to produce concrete of a given consistency by either increasing water content or maintains workability with a reduced amount of water.

1.6.2.5 Water Reducing and Accelerating Admixture—ASTM C 494

An admixture that reduces the quantity of mixing water required to produce concrete of a given consistency and accelerates the setting and early strength development of concrete.

1.6.2.6 Water Reducing and Retarding Admixture—ASTM C 494

An admixture that reduces the quantity of mixing water required to produce concrete of a given consistency and retards the setting of concrete.

1.6.2.7 Pozzolans—ASTM C 595, ASTM C 618

A siliceous and aluminous material, which in itself possesses little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.

1.6.2.8 Polymer Concrete

Concrete in which an organic polymer serves as the binder; also known as resin concrete; sometimes erroneously employed to designate hydraulic cement mortars or concretes in which part or all of the mixing water is replaced by an aqueous dispersion of a thermoplastic copolymer.

1.6.2.9 Polymer Cement Concrete

A mixture of water, hydraulic cement, aggregate, and a monomer or polymer; polymerized in place when a monomer is used.

1.6.2.10 Bonding Agent

A substance applied to a sound substrate to create a bond between it and a succeeding layer or adjacent concrete placement.

1.6.3 Fly Ash as an Admixture to Concrete

1.6.3.1 Laboratory Testing

Laboratory testing shall be required to determine the optimum proportion of fly ash to cement for obtaining the specific concrete strength. This testing shall determine: (A) If an air entrainment admixture is necessary; (B) the maximum allowable loss of ignition for Class F; (C) Sulfate resistance. Fly ash shall conform to ASTM C 618; Class C or Class F.

1.6.3.2 Documentation

Each shipment of fly ash used on a project shall have a certificate of compliance which includes the following.

- (a) Name of supplier.
- (b) Source of fly ash.
- (c) Type of fly ash with certified test numbers representing the material being shipped and that the test numbers meet the specifications of ASTM C 618.
- (d) Consignee and destination of the shipment.
- (e) Railroad car number or truck identification number.
- (f) A unique unrepeatable order number or other identification number for each shipment.

1.8.4 Form Coating and Release

The inside surfaces of forms shall be coated with a ready-to-use, nonstaining Form Release Agent. A thin film shall be applied to all surfaces that will be in contact with the fresh concrete.

1.9 DETAILS OF REINFORCEMENT

1.9.1 Surface Conditions of Reinforcement

Reinforcement at the time concrete is placed shall be free from mud, oil, or other non-metallic coatings that adversely affect bonding capacity. Epoxy coatings of bars, wire, and welded wire fabric conforming to standards in these specifications are permitted.

Reinforcement, except prestressing tendons, with rust, mill scale, or a combination of both shall be considered as satisfactory, provided the minimum dimensions, including height or deformations, and weight of a hand wire-brushed test specimen are not less than the applicable ASTM specification requirements.

Prestressing tendons shall be clean and free of oil, dirt, scale, pitting and excessive rust. A light oxide is permissible.

1.9.2 Fabrication

Reinforcement shall be prefabricated to the dimensions shown on the plans. Reinforcement shall be bent cold, and shall not be bent or straightened in a manner that will injure the material. Bars with kinks or bends not shown on the plans shall be rejected. Hot bending of reinforcement will be permitted only when the entire operation is approved by the Engineer. Bars partially embedded in concrete shall not be field bent, except as shown on the design drawings or permitted by the Engineer. When epoxy-coated or zinc-coated (galvanized) reinforcing bars are field bent, damaged coating shall be repaired in accordance with Subarticle 1.5.3.4.

Diameter of bends measured on the inside of the bar shall be as shown on the plans. When diameter of bend is not shown, minimum bend diameter shall be in accordance with Part 2.

Unless otherwise specified by the Engineer, the tolerance in fabricated lengths of bars from that shown on the placing drawings shall be plus or minus 1 inch for bar sizes #11 and under and 2 inches for bar sizes #14 and #18; the tolerance in out to out dimensions of hooks shall be plus or minus 1/2 inch; the tolerance in out to out dimensions of stirrups and ties shall be plus or minus 1 inch and the maximum angular deviation of 90 degree hooks or bends shall be 1/2 inch per foot.

1.9.3 Provisions for Seismic Loading

For structures located in Seismic Zones, consideration must be given to reinforcement details that will provide adequate ductility to allow reinforcement to be strained beyond yield to allow the structure to absorb the energy of an earthquake.

1.9.4 Placing of Reinforcement

1.9.4.1 General

Reinforcement, prestressing tendons and ducts shall be accurately placed and adequately supported before concrete is placed, and shall be secured against displacement within permitted tolerances. Tie wire shall be 16-1/2 gage or heavier, black-annealed. Welding of crossing bars shall not be permitted for assembly of reinforcement unless authorized by the Engineer.

Reinforcing bars shall not be cut in the field except when authorized by the Engineer.

When epoxy-coated or zinc-coated (galvanized) reinforcing bars are cut in the field, the ends of the bars shall be coated with the same material that is used for the repair of coating damage and shall be repaired in accordance with Subarticle 1.5.3.4.

1.9.4.2 Tolerances

Unless otherwise specified by the Engineer, reinforcement, prestressing tendons, and prestressing ducts shall be placed in flexural members, walls and compression members within the following tolerances:

(a) Clear distance to side forms and resulting concrete surfaces and clear distance to formed and resulting concrete soffits:

When member size is 12 in. or less	± 3/8 in.
When member size is over 12 in. but not over 2 ft.	± 1/2 in.
When member size is over 2 ft.	± 1 in.

Concrete cover measured perpendicular to concrete surface:

When member size is 12 in. or less	- 3/8 in.
When member size is over 12 in.	- 1/2 in.

Reduction in cover shall not exceed one-third specified concrete cover.

Reduction in cover to formed soffits shall not exceed 1/4 in.

Tolerances shall not permit a reduction in cover except as shown above.

(b) Tolerance on minimum distance between bars shall be minus 1/4 in.

(c) Tolerance in uniform spacing of reinforcement from theoretical location shall be ± 2 in.

(d) Tolerance in uniform spacing of stirrups and ties from theoretical location shall be ± 1 in.

(e) Tolerance for longitudinal location of bends and ends of bars shall be ± 2 in., except at discontinuous ends of members where the tolerance shall be $\pm 1/2$ in.

(f) Tolerance in length of bar laps shall be minus 1-1/2 in.

(g) Tolerance in embedded length shall be minus 1 in. for #3 - #11 bars and minus 2 in. for #14 and #18 bars.

When it is necessary to move bars to avoid interference with other reinforcement, conduits, or embedded items by an amount exceeding the specified placing tolerances, the resulting arrangement of bars shall be approved by the Engineer.

(h) Tolerance in location of prestressing tendons shall be $\pm 1/4$ in. except in precast slabs, prestressing tendons and prestressing ducts shall be placed within a horizontal tolerance of ± 1 in. in any 15 ft. of tendon length.

(i) In precast elements the bearing plates shall be concentric with the tendons and tolerance for the perpendicularity with tendons in concrete shall be ± 1 degree.

1.9.4.3 Bar Supports and Side Form Spacers

(a) Unless otherwise specified by the Engineer, reinforcement supported from the ground shall rest on precast concrete blocks not less than 4 in. square, and having a compressive strength equal to or greater than the specified compressive strength of the concrete being placed. Reinforcement supported from formwork shall rest on bar supports and spacers made of concrete, metal, plastic, or other materials approved by the Engineer.

(b) Where noted on the plans and at all formed surfaces that will be exposed to the weather in the finished structure, bar supports and side form spacers spaced no further than 4 feet 0 inches on center shall be provided. Bar supports and spacers and all other accessories within 1/2 in. of the concrete surface shall be noncorrosive or protected against corrosion.

(c) Epoxy-coated reinforcing bars supported from formwork shall rest on coated wire bar supports, or on bar supports made of dielectric material and other acceptable materials. Wire bar supports shall be coated with dielectric material for a minimum distance of 2 in. from the point of contact with the epoxy-coated reinforcing bars. Reinforcing bars used as support bars shall be epoxy-coated. In walls having epoxy-coated reinforcing bars, spreader bars where specified shall be epoxy-coated. Proprietary combination bar clips and spreaders used in walls with epoxy-coated reinforcing bars shall be made of corrosion-resistant material or coated with dielectric material.

(d) Zinc-coated (galvanized) reinforcing bars supported from formwork shall rest on galvanized wire bar supports coated with dielectric material, or on bar supports made of dielectric material or other acceptable materials. All other reinforcement and embedded steel items in contact with galvanized reinforcing bars, or within a minimum clear distance of 2 in. from galvanized reinforcing bars unless otherwise required or permitted, shall be galvanized.

(e) Epoxy-coated reinforcing bars shall be fastened (tied) with plastic-coated or epoxy-coated tie wire; or other materials authorized by the Engineer.

(f) Zinc-coated (galvanized) reinforcing bars shall be fastened (tied) with zinc-coated tie wire, or nonmetallic-coated tie wire, or other materials authorized by the Engineer.

1.9.4.4 Draped Fabric

When welded wire fabric with wire size not greater than W5 or D5 is used for slab reinforcement in slabs not exceeding 10 ft. in span, the reinforcement may be curved from a point near the top of the slab over the support to a point near the bottom of the slab at mid-span, provided such reinforcement is either continuous over, or securely anchored, at the support.

1.9.5 Spacing of Reinforcement

Spacing of reinforcement shall be as shown on the plans. When spacing of reinforcement is not shown, spacing shall be in accordance with Part 2 for reinforcing bars, and Part 17, for prestressing tendons and ducts.

1.9.6 Concrete Protection for Reinforcement

Concrete cover for reinforcement shall be as shown on the plans. When concrete cover is not shown, minimum concrete cover shall be in accordance with Part 2, Section 2.6 for bars and wire, and Part 17, Article 17.3.2 for prestressing tendons and ducts.

1.9.7 Future Bonding

Exposed reinforcement intended for bonding with future extensions shall be protected from corrosion in an approved manner.

1.10.3 Watertight Construction Joints

Construction joints shall not be used in watertight construction unless shown on the plans or authorized by the Engineer.

Where a construction joint is required to resist water pressure, special care shall be taken in finishing the surface to which the succeeding concrete is to be bonded. The consistency of the concrete shall be carefully controlled and the surface shall be protected from loss of moisture as described in article 1.17.4.

Where construction joints are required to be watertight, a continuous keyway shall be constructed in the face of the first section of concrete placed with an approved water stop embedded in this first placement. One half of the water stop is embedded in the first pour and the remaining material shall be embedded in the adjacement placement. The concrete shall be thoroughly vibrated to insure uniform contact over the entire surface of the water stop. The water stop shall be in conformance to Corps of Engineers Specification CRD C 572 (PVC) or CRD C 513 (Rubber).

1.10.4.3 Procedure for Forming Isolation (Expansion) Joints

Isolation Joints allow for differential movement in all directions of the concrete in either side of the joint. These are frequently referred to as Expansion Joints.

Isolation Joints shall be installed around columns, in walls, slabs and footings, etc. as shown on the plans or as specified by the Engineer.

Jointing materials shall be in conformance to ASTM D 994 or ASTM D 1751. There shall be no connection across the joint by welded wire fabric, keyways or reinforcing steel (dowel bars).

1.10.5 Expansion Joint Walls

Expansion Joints between the finished surface and the waterstop shall be filled with a material similar to a 1/2 inch thick strip of Premoulded Asphaltic Expansion Joint, or a polyurethane or polysulfide joint sealing compound.

1.13.9 Bonding

Before new concrete is placed against hardened concrete, the surface of the hardened concrete shall be cleaned and all laitance removed. Immediately before new concrete is placed, the existing surfaces shall be thoroughly wetted and all standing water removed. Prior to placing fresh concrete, apply a bonding layer of mortar, usually 1/8 inch to 1/2 inch in thickness, which is spread on the moist and prepared hardened concrete surface. In lieu of mortar, a suitable commercial bonding agent may be used, when applied in accordance with manufacturer's recommendations.

1.17.4 Membrane Curing

In lieu of wet curing, a concrete curing compound in full conformance to ASTM C 309 may be used, with the approval of the Engineer.

Liquid Membrane-Forming Curing Compounds shall meet the requirements of:

ASTM C 309

Type 1 (Clear)

Type 1D (Clear with Fugitive Dye)

Type 2 (White Pigmented)

Class B (Solids Restricted to Resin Only)

The compounds shall be applied to all exposed concrete surfaces except those areas where concrete or other materials are to be bonded, such as construction joints or areas to be dampproofed or waterproofed.

The compound shall be sprayed on finished surfaces as soon as the surface water has disappeared. Spraying equipment shall be of the pressure-tank type with mist producing spray orifice. If forms are removed during the curing period, concrete shall be sprayed lightly with water and the moistening continued until the surface will not readily absorb more water. The Curing Compound shall then be sprayed on the concrete surface as soon as the moisture film has disappeared.

1.21 PENETRATING WATER REPELLENT TREATMENT OF CONCRETE SURFACES

1.21.1 General

When called for on the plans, in the specifications or ordered by the Engineer the following requirements shall be applicable to the treatment of exposed concrete surfaces upon completion of the structure or pre-cast member. Water repellent treatment is not intended to be used on surfaces subject to hydrostatic pressure.

1.21.2 Surface Preparation

- (a) Concrete surfaces shall be cleaned by removing all traces of curing compounds, laitance, dirt, salt, oil, grease, fluids or other foreign material that would block the pores of the surface.
- (b) Concrete surface shall be clean and dry or as recommended by manufacturer.
- (c) The cleaning process shall not alter the existing surface finish unless specified by the Engineer as an intentional part of the design.

1.21.3 Environmental Requirements

- (a) Volatile Organic Compound regulations may vary by individual state. Therefore, it is mandatory that materials selected for use be in total conformance to the applicable legislation of the state within which the work will be performed.
- (b) Ambient temperatures shall be as specified by manufacturer but not less than 40°F. or greater than 100°F.

- (c) No rain predicted for a minimum of hours after application.
- (d) No precipitation within 24 hours preceding application.
- (e) No wind of velocity that will cause an improper application rate or drift.
- (f) Adjoining surfaces of other materials shall be protected unless solvent carrier is certified as harmless to these materials by water repellent manufacturer.

1.21.4 Application

- (a) The penetrating water repellent treatment solution shall be applied in strict accordance with manufacturer's instructions and not diluted or altered unless specified by the manufacturer.
- (b) Surface treatment of new concrete prior to 28 days curing is not permitted, unless approved by the Engineer.
- (c) The sealer manufacturer should be consulted on the recommended treatment of cracks.
- (d) Follow all safety precautions required by occupational jurisdiction.

1.21.5 Materials

- (a) The penetrating water repellent material shall consist of an isobutyltrialkoxo silane, n-octyltrialkoxo silane or iso-octyltrialkoxo silane dissolved in a suitable solvent that will produce a hydrophobic surface covalently bonded to the concrete.
- (a) Qualities of the material to be furnished for the project shall be tested and results certified by an independent testing laboratory with report provided to the owner. The following tests shall be performed on standardized laboratory specimens:
 - 1. Water Penetration: ASTM C642—50 Day Soak less than 1% Absorption (untreated specimen 4% + 0.2% absorption)
 - 2. Water Penetration: National Cooperative Highway Research Program Report 244—21 Day Soak—Effective Average Minimum 80% (Series II)
 - 3. Vapor Transmission: National Cooperative Highway Research Program Report 244—Minimum 100%
 - 4. Surface Appearance: No change in surface appearance or texture
 - 5. Penetration: Oklahoma DOT OHD L-34 Visible Average 0.15 in.
 - 6. Drying Time: Dry and ready for use 1 hour after application
 - 7. Accelerated Weathering: ASTM G-23—2000 hours arc weatherometer—Maximum 3% loss of effectiveness
 - 8. Water Penetration: Alberta DOT Type 1 Class B minimum
 - 9. Salt Water Ponding: AASHTO T-259—Maximum 1.50 lbs. per cubic yard at 1/16 in. to 1/2 in.; 0.75 lbs. per cubic yard at 1/2 in. to 1 in.
 - 10. Traction—ASTM E303—No change when treated surface is compared to control surface. Measured in British Pendulum Numbers.

1.21.6 Quality Assurance

- (a) The manufacturer shall provide written certification of the quality of the product being offered and issue a warranty as to its effectiveness when it is applied in accordance with the manufacturer's specifications.
- (b) Manufacturer shall have an established Quality Assurance Program with the Program available to the owner or buyer.
- (c) Pre-Test: An eight square foot test panel on the job shall be treated and evaluated in accordance with the primary water repellent manufacturer's recommendations and written test procedures which would allow the water repellent to cure for a minimum of 5 days. Two test cores (minimum 3 in. diameter and 3 in. deep) should be taken at a location determined by the

Engineer. In the presence of the manufacturer, or one of its representatives, the cores should be split by chisel. One core should be sent to the manufacturer. The water repellent material shall have penetrated the core at least 1/8 in. (avg.) and shall appear as a band of non-wettable concrete.

- (d) Test Data: All test data submitted by the water repellent manufacturer must be data generated by an independent testing laboratory. Product tests must be totally controlled by testing laboratory. Specimens cannot be pre-treated by the manufacturer.

1.21.7 Deliver, Storage and Handling

- (a) Materials shall be delivered to job site in manufacturer's original undamaged containers with labels and seals intact.
- (b) Materials shall be stored in accordance with manufacturer's requirements and in dry area with a temperature range of not less than 32°F and not more than 120°F. Adequate ventilation shall be provided, away from sources of ignition.
- (c) Manufacturer's application instructions and Material Safety Data Sheet shall be consulted for additional safety instructions.

1.22 REPAIRS AND ANCHORAGE USING EPOXY MATERIALS

Epoxy materials should be chosen to provide for the requirements (i.e., viscosity, strength, flexibility, adhesion, etc.) of the specific repair to be performed. Epoxy materials shall be in conformance with ASTM C 881 and the specific type, grade and class is the selection of the Engineer.

COMMENTARY AND BIBLIOGRAPHY

C1.3 AGGREGATES

C1.3.2.1 General

Use of lightweight fine aggregate is not allowed because of the many difficulties and restrictions to its use.

C1.3.4.4 Concrete Making Properties

Use of lightweight fine aggregate is not allowed because of the many difficulties and restrictions to its use.

C1.5 REINFORCEMENT

C1.5.4 Bending and Straightening (Bibliography references 5 and 6)

Field bending and straightening of partially embedded reinforcement bars is discouraged but when this operation is required it should be closely controlled. Construction conditions that make field bending or straightening necessary also make it difficult to control the conditions under which it is done thus making field inspection even more critical.

There are numerous papers written on this subject with varying opinions on the best procedures to use. There is ongoing research that should supply additional test results to clarify current assumptions. A few of the current known factors that affected these standards are that:

1. Application of heat appears to be necessary to bend or straighten larger sized rebar but either over heating (above 1800°F) or under heating (between 450°F and 650°F) can create much reduced rebar strength or even cause failure.
2. Repeated bending and straightening weakens the metal and will result in failure even under the best controlled conditions.

3. Tight bending diameters decreases the metals strength.

The reworking of reinforcing bars that are partially embedded in concrete involves some level of risk and is not encouraged. Risks may be minimized by using reinforcement bars of a more ductile steel such as A706 rather than A615 in locations where field bending and/or straightening will be required. This is awkward from a constructability standpoint.

When field bending and straightening of partially embedded bars, for A615 grade 40 or grade 60 steel, is permitted by the Engineer, an example procedural guideline is the following:

1. Bars of size #3 through #7.
 - a. Bend or straighten bars cold (bars should be above freezing temperature).
 - b. Do not allow more than one cycle of bending and straightening.
 - c. Diameter of bends should conform to Table 2.4. Bends should not exceed 90°.
 - d. Bending should be done with as smooth an application of force as possible.
 - e. Straightening should be accomplished by using a steel pipe pushed tight against the bend and with application of force and reset periodically as follows:
 - i. Steel pipe should have inside diameter 1/8 to 3/8 inch larger than outside diameter of bar to be straightened.
 - ii. Steel pipe should be a minimum length of 8 inches times the bar number size of the bar to be straightened to provide sufficient leverage.
 - iii. Straightening pipe should be reset against the bar at 45 degrees for #4 and smaller bars and at 30 and 60 degrees for #5 to #7 bars.
 - iv. Workers must have a firm base from which to apply straightening pressure to reduce the risk of injury if the bar suddenly fails.
2. Bars of size #8 through #11.
 - a. Bend or straighten bars after preheating to 1100°F to 1500°F as measured with temperature sticks.
 - b. Concrete must be protected from exposure to excessive heat. If necessary protective insulation should be used.
 - c. Atmospherically cool bars. Do not expose to water or other cooling mediums.
 - d. Do not allow more than one cycle of bending and straightening.
 - e. Diameter of bends should conform to Table 2.4.
 - f. Bending should be done with as smooth an application of force as possible.
 - g. Straightening should be accomplished by using a steel pipe pushed tight against the bend and with application of force and reset periodically as follows:
 - i. Steel pipe should have inside diameter 1/8 to 3/8 inch larger than outside diameter of bar to be straightened.
 - ii. Steel pipe should be long enough to provide sufficient leverage.
 - iii. Straightening pipe should be reset progressively against the bar around the bend.
 - iv. Workers must have a firm base from which to apply straightening pressure to reduce the risk of injury if the bar suddenly fails.

C1.6 ADMIXTURES

There are two different types of fly ash produced from the combustion of ground or powdered coal.

Class C is produced from lignite or sub-bituminous coal and Class F is produced from burning anthracite or bituminous coal. Both classes have pozzolan properties that chemically react with calcium hydroxide at ordinary temperature to form compounds having cementitious properties.

Fly ash conforming to the physical properties of Class C and Class F per ASTM C 618 can be substituted as a mineral admixture in Portland cement concrete.

The most variable reaction of fly ash in concrete is the pozzolanic reactivity. Major factors affecting reactivity are fineness, glass content and silica or silica-plus-alumina content. These variables in fly ash, both chemical composition and relative proportions of different particle types and fineness, create wide variation in pozzolanic reactivity and cement efficiency for strength development. Direct test of strength development with lime or Portland cement are necessary to evaluate fly ashes in blended cement or concrete. ASTM C 311 for the Pozzolanic Activity Index with Portland cement specifies ratios of up to 30% fly ash 70% cement by weight. Concrete made with higher percentages of highly reactive pozzolanic fly ash may cause loss of strength at advanced stages of reaction because of partial decomposition of calcium silicate hydrate. Class F fly ash also reduces alkali aggregate reaction by about 20%.

C1.17 CURING AND PROTECTION

C1.17.4 Membrane Curing

With the emergence of new legislation designed to limit the amounts of Volatile Organic Compound (V.O.C.) emission, it is incumbent upon specifying Engineers to be cognizant of these new laws.

Volatile Organic Compound regulations may vary by individual state. Therefore, it is mandatory that materials selected for use be in total conformance to the applicable legislation of the state within which the work will be performed.

C1.21 PENETRATING WATER REPELLENT TREATMENT OF CONCRETE SURFACES

(Bibliography references 1 through 4)

C1.21.1 General

Penetrating sealers are primarily intended for use in sealing the surface of concrete structures against intrusion of water and chlorides. Of the 21 materials tested and addressed in National Cooperative Highway Research Program Report 244, only the silane exhibited a measurable penetration effect.

NCHRP Report 244:

"This silane material produces a non-wettable concrete surface to a depth of 0.10 in. The other materials tested in this project, including boiled linseed oil, generally do not produce a measurable penetration or a measurable thickness of non-wettable concrete. Most of these other materials are coatings and should not be referred to in specifications as 'penetrating sealers'."

With the emergence of new legislation designed to limit the amounts of Volatile Organic Compound (V.O.C.) emission, it is incumbent upon specifying Engineers to be cognizant of these new laws.

C1.21.2 Surface Preparation

(a) Surface preparation may be accomplished by:

- 1) High pressure water (hot or cold)
- 2) Chemical cleaners
- 3) Sandblasting
- 4) Shotblasting

(b) When high pressure water is employed, all surfaces shall be free of standing water or moisture at the time of the treatment which could restrict surface penetration.

C1.21.3 Environmental Requirements

There is some question of the effects of high temperature on water repellent treatments as one author states that high temperatures actually speed up the condensation reaction of monomeric silanes into oligomeric siloxanes. Because of this, application of treatment at temperatures over 100°F should be carefully considered.

C1.21.4 Application

Consult the manufacturer's material safety data sheet and application instructions for further safety information.

C1.21.6 Quality Assurance

(a) The owner of a concrete structure or buyer of a concrete sealer shall be satisfied that the manufacturer can furnish the quality assurance claimed. This can be done by comparing test results of the product against test results obtained by independent test studies, several of which are listed in the Bibliography of this section. The buyer or owner should also be satisfied that an agent or distributor who makes such claims or offers such a warranty has the full authority to do so by the manufacturer.

(b) The owner of a concrete structure or buyer of a concrete sealer should seek out an applicator (either owner's own employee or outside contractor approved by the manufacturer in order to validate its warranty.)

C1.22 REPAIRS AND ANCHORAGE USING EPOXY MATERIALS

A suitable Epoxy may be selected for inclusion with fine and/or coarse aggregate in an Epoxy concrete or included with a clean, dry, fine aggregate in an epoxy mortar. Epoxy resin can be used in chemical bonding systems as an adhesive for concrete or as a binder for mortars and concretes.

Epoxy materials may also be used neat (without the addition of aggregate) as a bonding agent, as a bonding coat for adhesion, as well as anchoring between metallic inserts and concrete when the spacing between the metallic insert and the interior wall of the bored hole in the concrete is 1/8" minimum. While the general rule for anchor bolt embedment is ten to fifteen times the bolt diameter the embedment shall be designed based upon loads to be carried.

BIBLIOGRAPHY

1. National Cooperative Highway Research Program, Report 244 Concrete Sealers for Protecting Bridge Structures, Transportation Research Board National Research Council, Washington, DC, December, 1981.
2. Evaluation of Sealers for Concrete Bridge Elements, Alberta Transportation & Utilities, Bridge Engineering Branch BRI/Reports/287PD010 August, 1987
3. Silane Chemical Protection of Bridge Decks, Oklahoma DOT Report FHWA/OK 86(4) December, 1986.
4. Application Mechanism of Silane Waterproofers, Edward McGettigan, Concrete International, ACI, October, 1990.
5. "Field Corrections to Rebars Partially Embedded in Concrete," *Concrete Reinforcing Steel Institute*, Engineering Data Report Number 12.
6. Reed, Frank O. "Develop Guidelines for Bending and Splicing Rebar," State of California Department of Transportation, June, 1984.

PART 2—REINFORCED CONCRETE DESIGN

Proposed revisions to Part 2 involve clarification of definitions and requirements of last year's major specification revisions as well as modifications required by research. Several changes have been made to various sections which affect design. Development length requirements for epoxy coated rebars has been added. Equations will be renumbered in Part 2 as part of this revision, but are not shown here because they are editorial in nature. Following are the specific changes proposed for Part 2.

ARTICLE 2.1.4

REVISE ARTICLE 2.1.4 TO READ AS FOLLOWS:

2.1.4 Buildings

Unless otherwise specified by local governing ordinances or state codes, all railway buildings shall be designed in accordance with the latest "Building Code Requirements for Reinforced Concrete (ACI 318)" of the American Concrete Institute, subject to design loads conforming to railway requirements.

ARTICLE 2.2.1

1. ADD THE FOLLOWING NOTATIONS AFTER A_{sf} :

A_{sk} = area of skin reinforcement per unit height in one side face, in.²/ft.—Article 2.8(b)

2. REVISE THE DEFINITION OF β_d TO:

β_d = ratio of maximum factored axial dead load to maximum total factored axial load, where the load is due to gravity effects only in the calculation of P_c in Eq. (2-43), or ratio of the maximum factored sustained lateral load to the maximum total factored lateral load in that level in the calculation of P_c in Eq. (2-44)—Article 2.34.2(e)

3. DELETE THE DEFINITIONS FOR A_1 AND A_2 :

4. ADD THE FOLLOWING NOTATIONS AFTER d_c :

d_p = diameter of round pile or cross sectional depth of H-pile at footing base—Articles 2.29.6(a) & 2.35.6(a)

ARTICLE 2.3.2(b)

1. REVISE THE SECOND SENTENCE TO READ:

"ASTM steel specifications, except for ASTM A706, shall be supplemented to require a report of material properties (chemical analysis) necessary to conform to welding procedures specified in . . ."

2. ADD THE FOLLOWING SENTENCE AT THE END OF THE ARTICLE:

If coated bars are to be welded, the Engineer should specify any additional requirements to those contained in AWS D1.4, such as removal of zinc or epoxy coating for welding and field application of new coatings in the weld region if protection is required.

ARTICLE 2.8(b)

REVISE TO READ AS FOLLOWS:

(b) If the depth of web exceeds 3 ft., longitudinal skin reinforcement shall be uniformly distributed along both side faces of the member for a distance $d/2$ nearest the flexural tension reinforcement. The area of skin reinforcement A_{sk} per foot of height on each side face shall be $\geq 0.012(d-30)$. The maximum spacing of the skin reinforcement shall be the smaller of $d/6$ or 12 in. Such reinforcement may be included in strength computations if a strain compatibility analysis is made to determine stresses in the individual bars or wires. The total area of longitudinal skin reinforcement in both faces need not exceed one-half of the required flexural tensile reinforcement."

Article 2.11.2

REVISE ARTICLE 2.11.2(a)(8) TO READ AS FOLLOWS:

(8) Spirals shall be held firmly in place and true to line by vertical spacers. For spiral bar or wire smaller than 5/8 in. diameter, a minimum of two spacers shall be used for spirals less than 20 in. in diameter, three spacers for spirals 20 to 30 in. in diameter, and four spacers for spirals greater than 30 in. in diameter. For spiral bar or wire 5/8 in. diameter or larger, a minimum of three spacers shall be used for spirals 24 in. or less in diameter, and four spacers for spirals greater than 24 in. in diameter.

ARTICLE 2.14

1. REVISE THE FIRST SENTENCE TO READ AS FOLLOWS:

Development length ℓ_d , in inches, of deformed bars and deformed wire in tension shall be computed as the product of the basic development length of (a) and the applicable modification factor or factors of (b) thru (e), but ℓ_d shall not be less than specified in (f).

2. DELETE PRESENT PARAGRAPH (e) AND INSERT THE FOLLOWING:

(e) The basic development length for bars coated with epoxy with cover less than 3 bar diameters or clear spacing between bars less than 6 bar diameters shall be multiplied by a factor of 1.5. The basic development length for all other epoxy coated bars shall be multiplied by a factor of 1.15. The product obtained when combining the factor for top reinforcement with the applicable factor for epoxy coated reinforcement need not be taken greater than 1.7.

(f) The development length ℓ_d shall be taken as not less than 12 in. except in the computation of lap splices by Article 2.22.3 and anchorage of shear reinforcement by Article 2.21.

ARTICLE 2.21(b)

REVISE TO READ AS FOLLOWS:

(b) The ends of single leg, single U-, or multiple U-stirrups shall be anchored by one of the following means:

(1) For #5 bar and D31 wire, and smaller, and for #6, #7, and #8 bars with f_y of 40,000 psi or less, a standard hook around longitudinal reinforcement.

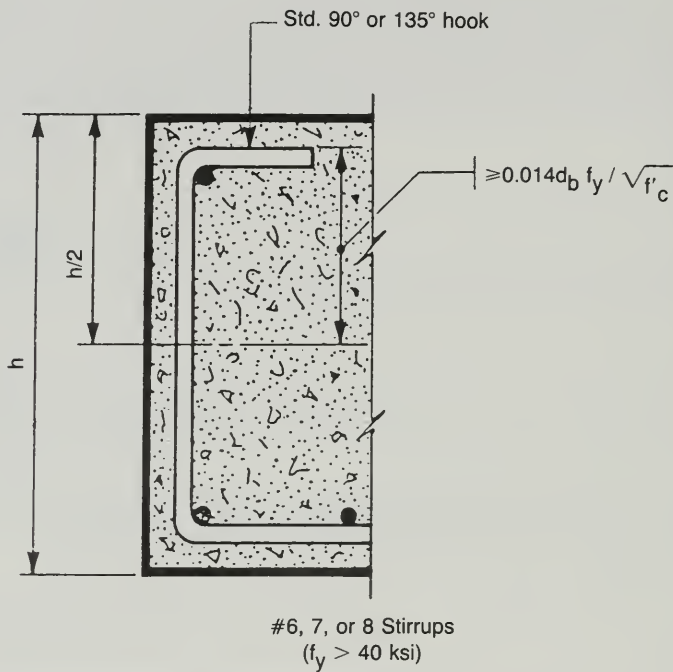
(2) For #6, #7, and #8 stirrups with f_y greater than 40,000 psi, a standard hook around a longitudinal bar plus an embedment between mid-height of the member and the outside end of the hook equal to or greater than $0.014 d_b f_y / \sqrt{f'_c}$.

(3) For each leg of welded plain wire fabric forming single U-stirrups, either:

- (A) Two longitudinal wires spaced at 2 in. spacing along the beam at the top of the U.
- (B) One longitudinal wire located not more than $d/4$ from the compression face and a second wire closer to the compression face and spaced at least 2 in. from the first wire. The second wire may be located beyond a bend or on a bend which has an inside diameter of at least 8 wire diameters.

ARTICLE 2.21(b)(2)

ADD THE FOLLOWING FIGURE AT THE END OF THE ARTICLE:



ARTICLE 2.26.1

REVISE TO READ AS FOLLOWS:

2.26.1 Concrete

For service load design, stresses in concrete shall not exceed the following:

- (a) Flexure
 - Extreme fiber stress in compression f_c $0.40 f'_c$
 - Extreme fiber stress in tension for plain concrete, f_t $0.21 f_r$
 - Modulus of rupture f_r , from tests, or if data are not available:
 - Normal weight concrete $7.5 \sqrt{f'_c}$
 - Lightweight concrete $6.3 \sqrt{f'_c}$
 - (b) Shear*
 - Beams and one-way slabs and footings:
 - Shear carried by concrete v_c , but not to exceed 95 psi $0.95 \sqrt{f'_c}$
 - Maximum shear carried by concrete plus shear reinforcement $v_c + 4 \sqrt{f'_c}$
 - Two-way slabs and footings:**
 - Shear carried by concrete v_c $(0.8 + \frac{2}{\beta_c}) \sqrt{f'_c}$
 - but not greater than $1.8 \sqrt{f'_c}$
 - (c) Bearing on loaded area f_b , but not to exceed 1050 psi $0.30 f'_c$
- Minimum distance from edge of bearing to edge of supporting concrete shall be 6 in.

ARTICLE 2.26.2

REVISE 2.26.2 Reinforcement TO READ AS FOLLOWS:

2.26.2 Reinforcement

For service load design, tensile stress in reinforcement f_s shall not exceed the following:

Grade 40 reinforcement 20,000 psi

Grade 60 reinforcement 24,000 psi

Fatigue Stress Limit—The range between a maximum tensile stress and minimum stress in straight reinforcement caused by live load plus impact shall not exceed the value obtained from:

$$f_f = 21 - 0.33 f_{\min} + 8(r/h)$$

where f_f = stress range in steel reinforcement, ksi

$f_{\min}$ = algebraic minimum stress level, tension positive, compression negative, ksi.

r/h = ratio of base radius to height of rolled-on transverse deformations; when the actual value is not known, use 0.3.

Bends in primary reinforcement shall be avoided in regions of high stress range.

ARTICLE 2.29.1

ADD A NEW PARAGRAPH AS FOLLOWS:

(d) For tapered webs, b_w shall be the average width or 1.2 times the minimum width, whichever is smaller.

ARTICLE 2.29.2

1. ADD FOOTNOTE TO TITLE AND BOTTOM OF PAGE 8-2-31 AS FOLLOWS:

2.29.2 Permissible Shear Stress**

**The value of $\sqrt{f'_c}$ used in computing v_c in Article 2.29.2 shall not be taken greater than 100 psi.

2. REVISE 2.29.2(b) AS FOLLOWS:

“(b) Shear stress carried by concrete v_c , for members subject to shear and flexure only, may be . . .”

3. **ARTICLE 2.29.2(c).** REVISE EQUATION (2-8) TO READ AS FOLLOWS:

$$v_c = 0.9 \left(1 + \frac{0.0006N}{A_g} \right) \sqrt{f'_c}$$

ARTICLE 2.29.3

1. REVISE PARAGRAPH (d) TO READ AS FOLLOWS:

(d) When $(v - v_c)$ exceeds $2 \sqrt{f'_c}$, maximum spacings given in Article 2.10.3 shall be reduced by one-half.

2. ADD A NEW PARAGRAPH AS FOLLOWS:

(f) When flexural reinforcement located within the width of a member used to compute the shear strength is terminated in a tension zone, shear reinforcement shall be provided in accordance with Article 2.13.1(f).

ARTICLE 2.29.4(c)(3) and ARTICLE 2.35.4(c)(3)

REVISE DEFINITION OF λ AS FOLLOWS:

where $\lambda = 1.0$ for normal weight concrete and 0.85 for lightweight concrete.

ARTICLE 2.29.5

ADD NEW PARAGRAPH (e)(3) AS FOLLOWS:

- (3) All beam shear reinforcement shall extend into cast-in-place deck slabs. Extended shear reinforcement may be used in satisfying the minimum tie reinforcement.

ARTICLE 2.29.6

1. IN ARTICLE 2.29.6(a)(2), CHANGE THE WORD “PERIPHERY” TO “PERIMETER” (two places).

2. ADD THE FOLLOWING AFTER 2.29.6(a)(2):

(3) At footings supported on piles the shear on the critical section shall be determined in accordance with:

- (A) Entire reaction from any pile whose center is located $d_p/2$ or more outside the critical section shall be considered as producing shear on that section.
- (B) Reaction from any pile whose center is located $d_p/2$ or more inside the critical section shall be considered as producing no shear on that section.
- (C) For intermediate positions of pile center, the portion of the pile reaction to be considered as producing shear on the critical section shall be based on linear interpolation between full value at $d_p/2$ outside the section and zero value at $d_p/2$ inside the section.

3. ARTICLE 2.29.6(c) REVISE TO READ AS FOLLOWS:

(c) Design shear v shall not exceed the smallest v_c given by Equation (2-25) or (2-26) unless shear reinforcement is provided in accordance with (d).

$$v_c = \left(0.8 + \frac{2}{\beta_c} \right) \sqrt{f'_c} \quad (2-25)$$

or

$$v_c = \left(0.8 + \frac{\alpha_s d}{b_o} \right) \sqrt{f'_c} \quad (2-26)$$

but not greater than $1.8 \sqrt{f'_c}$. β_c is the ratio of long side to short side of concentrated load or reaction area. α_s is 20 for interior concentrated loads or reaction areas, 15 for edge concentrated loads or reaction areas, and 10 for corner concentrated loads or reaction areas.

ARTICLE 2.33.3

DELETE THE DEFINITION OF β_d UNDER EQUATION 2-36.

ARTICLE 2.35.1

ADD A NEW PARAGRAPH AS FOLLOWS:

(d) For tapered webs, b_w shall be the average width or 1.2 times the minimum width, whichever is smaller.

ARTICLE 2.35.2

1. ADD FOOTNOTE TO TITLE AND BOTTOM OF PAGE AS FOLLOWS:

2.35.2 Permissible Shear Stress**

**The value of $\sqrt{f'_c}$ used in computing v_c shall not be taken greater than 100 psi.

2. ARTICLE 2.35.2(b) REVISE TO READ AS FOLLOWS:

“(b) Shear stress carried by concrete v_c , for members subject to shear and flexure only, may be . . .”

ARTICLE 2.35.3

1. REVISE PARAGRAPH (d) TO READ AS FOLLOWS:

(d) When $(v - v_c)$ exceeds $4\sqrt{f'_c}$, maximum spacings given in Article 2.10.3 shall be reduced by one-half.

2. ADD A NEW PARAGRAPH AS FOLLOWS:

(f) When flexural reinforcement located within the width of a member used to compute the shear strength is terminated in a tension zone, shear reinforcement shall be provided in accordance with Article 2.13.1(f).

ARTICLE 2.35.5

1. REVISE PARAGRAPH (d) AS FOLLOWS:

(d) Horizontal shear may be investigated by computing, in any segment not exceeding one-tenth of the span, the actual change in compressive or tensile force to be transferred, and provisions made to transfer that force as horizontal shear between interconnected elements. The factored horizontal shear stress shall not exceed the horizontal shear strength v_{uh} in accordance with paragraph (c), except that length of segment considered shall be substituted for d .

2. ADD A NEW PARAGRAPH (e)(3) AS FOLLOWS:

(3) All beam shear reinforcement shall extend into cast-in-place deck slabs. Extended shear reinforcement may be used in satisfying the minimum tie reinforcement.

ARTICLE 2.35.6

1. ADD THE FOLLOWING AFTER 2.35.6(a)(2):

(3) At footings supported on piles the shear on the critical section shall be determined in accordance with:

(A) Entire reaction from any pile whose center is located $d_p/2$ or more outside the critical section shall be considered as producing shear on that section.

(B) Reaction from any pile whose center is located $d_p/2$ or more inside the critical section shall be considered as producing no shear on that section.

(C) For intermediate positions of pile center, the portion of the pile reaction to be considered as producing shear on the critical section shall be based on linear interpolation between full value at $d_p/2$ outside the section and zero value at $d_p/2$ inside the section.

2. IN ARTICLE 2.35.6(a)(2), CHANGE THE WORD “PERIPHERY” TO “PERIMETER” (two places).

3. REVISE ARTICLE 2.35.6(a) TO READ:

“. . . shall be governed by the more severe of the following conditions:”

4. ARTICLE 2.35.6(b) & (c), REVISE TO READ AS FOLLOWS:

(b) Factored shear stress for two-way action shall be computed by:

$$v_u = \frac{V_u}{\phi b_o d} \quad (2-60)$$

where V_u and b_o are taken at the critical section defined in (a)(2).(c) Factored shear stress v_u shall not exceed the least v_c given by Equations (2-61), (2-62), or (2-63) unless shear reinforcement is provided in accordance with (d).

$$v_c = \left(\frac{\alpha_s d}{b_o} + 2 \right) \sqrt{f'_c} \quad (2-61)$$

$$v_c = \left(2 + \frac{4}{\beta_c} \right) \sqrt{f'_c} \quad (2-62)$$

$$v_c = 4 \sqrt{f'_c} \quad (2-63)$$

β_c is the ratio of long side to short side of concentrated load or reaction area. α_s is 40 for interior concentrated loads or reaction areas, 30 for edge concentrated loads or reaction areas, and 20 for corner concentrated loads or reaction areas.

ARTICLE 2.38

REVISE THE EQUATION TO READ:

$$f_f = 21 - 0.33 f_{\min} + 8(r/h)$$

where f_f = stress range in steel reinforcement, ksi.
 $f_{\min}$ = algebraic minimum stress level, tension positive, compression negative, ksi.
 r/h = ratio of base radius to height of rolled-on transverse deformations: when the actual value is not known, use 0.3.

Bends in primary reinforcement shall be avoided in regions of high stress range.

PART 12—CANTILEVER POLES

The current Part 12 of Chapter 8 provides specifications on Concrete Poles. The new Part 12 has been retitled and expanded to provide specifications for cantilever pole design and installation, utilizing recommendations in the current Part 12. A copy of the new Part 12 may be obtained by writing AREA Headquarters and enclosing \$2.00.

PART 14—REPAIR AND REHABILITATION OF CONCRETE STRUCTURES

A complete revision and enlargement of existing material in Part 14 has been completed. Substantive revisions to Part 14 include the addition of a Section on "Repair Methods of Prestressed Members." A copy of the new Part 14 may be obtained by writing AREA Headquarters and enclosing \$2.00.

PART 22—GEOTECHNICAL SUBSURFACE INVESTIGATION

A general updating and amplification of the specifications for Part 22 has been completed. New Sections 22.11 on In-Situ Testing of Soil and 22.12 on Backfilling of Bore Holes have been added. A copy of the new Part 22 may be obtained by writing AREA Headquarters and enclosing \$2.00.

Proposed 1992 Manual Revisions To Chapter 12 - Rail Transit

Chapter 12 material for Part 2—Rail Transit Corridor Planning has been completed. The proposed initial material for Part 2 follows:

Part 2 Rail Transit Corridor Planning

2.1 INTRODUCTION

This section covers an area best described as conceptual engineering. It describes the steps and considerations which are normally addressed when identifying and analyzing rail transit corridors. A general synopsis of the planning considerations is included to familiarize the engineer with the overall concepts for studying a potential corridor.

A rail transit corridor evaluation study is typically performed by a multi-disciplined team. It is important that engineers be included on this team so that practical engineering considerations are recognized from the earliest stages of project development. This team must work closely with the agency sponsoring the study, as well as the different levels of government and agencies involved in the area to be studied. The study team staffing plan should include environmental impact specialists, financial analysts, and government representatives. In an area with an existing transit system, representatives of the operating authority should also be included.

The first step when starting an analysis is to define clear project goals. Some goals will be set by the sponsor and some will be self-evident. Other goals need to be defined by the project team before an effective study can proceed. Included in this section is a discussion of what the most common goals are and how to achieve them. Once the goals are set, the gathering of data and projections can begin.

Some types of planning data will be readily available. Other data must be specifically developed for the project, and will take a period of time to produce. Ridership projections and economic analyses, in particular, can take long periods of time to obtain, especially if they are to be accurate. Ridership estimates must ensure reasonable conclusions and supportable projections.

The corridors to be analyzed should be identified early in the process, so that data collection can proceed effectively without wasting time and effort on non-viable corridors. Corridor studies are often broken down into conceptual and preliminary phases. The conceptual study phase attempts to look at all choices, but this is done only with the amount of detail necessary to eliminate the worst choices. The preliminary study phase then proceeds with a more in-depth analyses to arrive at the evaluation team's recommendations.

The criteria for evaluating the potential corridors and routes need to be set by the entire study team, with due regard for the sponsoring agency goals. In the case of an initial line in a location with no previous transit experience, local decision makers may be unfamiliar with rail transit planning issues. In these circumstances, the responsibility of the planning team is increased and the assignment of the best qualified people is essential.

The decision to build a rail transit corridor will have extensive long-term impacts on the region. Due to these long-term effects, the choice of rail transit technology must be closely related to the potential ridership and the perceptions of the public. The proposed rail transit system must be perceived as a socio-economic benefit. It must also interface with and improve the existing regional transportation system. Finally, it must serve the future transportation needs of the area.

Major areas to be addressed in identifying rail corridors go beyond engineering and include:

- Planning
- Urban Land Economics
- Environmental Issues
- Finances
- Operations
- Politics

Engineers working on corridor studies need to have familiarity with the above disciplines, and recognize that they will have strong effects on the eventual conclusions and recommendations. Likewise, the choice of corridor/route and vehicle technologies often affect each other.

The corridor evaluation section includes a discussion of some of the factors important when selecting a vehicle technology. Alignment, station locations, passenger loadings and travel time are obvious factors. However, technology changes, such as those in car design, control and power systems, can cause a cascade effect in other areas.

Lastly, the strategy for the implementation of the corridor study needs to be developed. This includes phasing, land purchases, financing, approvals, public relations and design/construction planning.

2.2 CORRIDOR PLANNING GOALS

2.2.1 General

In the planning for rail transit corridors, it must always be kept in mind that the central purpose is to move people. More particularly, to move people efficiently and safely with an appropriate degree of comfort. In defining a rail transit project, practical tradeoffs must be made between ideal planning objectives and adherence to rigid design criteria. Many other sub-goals and criteria must also be considered, but their relationship to the central goal of effectively moving people must always be kept in mind. Examples of major criteria include:

Capacity—The characteristic of rail transit that gives it special significance in corridors is its ability to handle large volumes of people on minimal rights-of-way. There are systems operating that move as many as 60,000 persons per hour per track in the peak travel direction. Utilizations of 500-700 persons per track per minute may be more reasonable to avoid unfavorable public reaction to crush loading. However, the 1,000 person per minute capability can be obtained.

Rail transit's high volume capabilities suggest that its primary goal is to move large volumes of people, particularly during peak travel hours. Various operating patterns (local, express service, zone service, skip-stop service) may be considered to tailor the system to passenger demand. Capacity to handle future demand increases requiring additional tracks and ability to bypass stations (e.g. express or zone service) should be considered in the planning process.

Land Usage—Due to rail transit's high volume capability, it is particularly well suited to service points of high density land utilization. In these situations, other vehicles move about only with difficulty and large amounts of land and structures are necessarily devoted to streets, highway structures and parking.

A central goal for rail transit corridors is to feed or link these areas of high density land usage, or to act as a catalyst for high density development. Rail transit allows much more dense commercial, business, and residential development than is possible with other transportation technologies. As such, rail transit can be an asset in planning and stimulating real estate development in accordance with community land use goals.

Energy—High capacity rail transit uses much less energy per passenger mile produced than the single occupant automobile. Therefore, an important goal is to couple highway systems to rail corridor systems using fringe or suburban parking developments. In this manner the energy-inefficient automobile portion of the trip can be shortened, and lower cost land can be utilized for parking.

2.2.2 User Needs

The success of any rail transit corridor will be dependent on its ability to attract riders. The service must be convenient, predictable, pleasant, and economical to the user. Both the infrastructure and the rolling stock must support these needs. Categorized below are various attributes that may be considered important to the attractiveness of service:

Convenience—Rail corridor stations must be convenient to destination points and facilities such as station parking lots. Pedestrian mobility to and around stations must be direct and without obstruction. The practical pedestrian radius will be influenced by length of walk, surroundings, climate, and local preferences.

For destinations beyond walking distance, convenient interface facilities with connecting transportation systems are a must. Timing of connections at interface points is particularly important.

Frequency of service and perceived speed are other important characteristics affecting convenience. High density systems commonly operate on as little as 90 second headways. Moderate ridership densities can use 10-15 minute headways, while longer headways are often used in commuter rail service. Various types of operating patterns (express, zone, skip-stop, etc.) may be used to reduce travel times.

Reliability—Of all the characteristics that will make the rail transit corridor attractive, reliability of service may be the most important. Transit riders do not have a sense of control. The system must not frustrate them or make them want to regain control (i.e., return to a private auto). Significant variations from expected performance cannot be tolerated.

Reliability starts with dependable, maintainable mechanical equipment, electrical facilities, and infrastructure. To the extent possible, maintenance must be accomplished without disrupting or altering service. The system must also be resistant to adverse weather conditions such as snow, heavy rain, or fog.

Another aspect of reliability occurs at connections. Undependable or overly long connections are annoying, fare machines or turnstiles that don't work are frustrating, and uncertain parking facilities make the trip difficult. Techniques such as timed transfers, dependable machines, and user-friendly designs that promote the sense of reliability must be included in system goals.

Ambiance—The ride quality, rail vehicles, stations, and station access must be pleasant. Station designs should provide shelter from wind and weather, and provide a feeling of security. Stations (and their neighborhoods) must be "pedestrian friendly." Activity centers such as small shops can be integrated into station designs to improve the appearance and vitality of the station environment.

While there is a necessary level of reliability and attractiveness to generate the volume of passengers required for support of the rail corridor, overspending on details that add little to convenience, reliability, general ambiance, utility of construction or efficiency of operation and maintenance should be avoided.

Reasonable Fare Structure—Studies are required to suggest an appropriate fare structure and to designate the sources of additional funding. This additional funding typically carries from 15 to 65 percent of the cost of operations. The additional funding must be derived from a long-term, dependable source.

2.2.3 Economic Acceptance

Only a portion of the population will ride the rail transit corridor. Yet, the presence of the rail transit corridor will affect the whole community through its influence on highway traffic volumes and density of land usage. It is important that the rail transit corridor be understood and accepted by the community as a whole, because of the rail line's impact on the surroundings and its need for some form of public subsidy. A definite effort should be made to quantify the costs and benefits of all transportation modes in the community, including rail transit.

2.2.4 Environmental Acceptance

Environmental acceptance goes well beyond the common restrictions on air and water pollution. It encompasses the question "is the proposed rail corridor compatible with the character and feelings of this community?" A goal of the rail corridor development is to pass this community test. A number of factors must be considered, including air quality, noise, vibration, visual appearance, travel time, traffic congestion, blocking of streets, taking of property, dislocation of neighborhoods, blocking of views, construction disruptions, etc.

2.2.5 Social Acceptance

Modern day society requires that certain social goals be met when providing transit services. These generally require an equality of mobility for all persons in the community. Communities are unique and the relationship of their social goals to the rail transit corridor must be aired and decided.

2.2.6 Safety

The corridor safety goal is that it must be, on a per trip basis, at least as safe as the existing alternatives. A number of particular details for attention are categorized below:

Train movement—By far the most important safety matters in rail corridor operations are speed and control of train movement. The irrevocable goal is that safe separation distances be maintained at all times and that there be no collision or hazard of accident between trains.

Infrastructure—Design and engineering of tracks, bridges, and tunnels utilize well-developed safe practices and codes. The goal for infrastructure is that it be maintainable and in accordance with all applicable safety codes.

Electrical hazards—Systems employing overhead or third rail power distribution must include protective designs for both the public and their own employees. Access to overhead wires must be denied at bridges; third rail should employ covers, and be located on secure right-of-way.

Vehicular conflicts—Grade crossings accidents are the principal cause of human injury due to railroad operations. Collisions between highway vehicles and rail vehicles must be prevented. Systems employing automatic train operation must be isolated from all uncontrolled activity such as vehicles and pedestrians at grade. This isolation includes the system's own maintenance activities.

Pedestrian safety—Stations, station platforms, stairways, and escalators must include safety considerations in their design. Problems of car door safety and platform gap awareness are important focuses for safety on high density systems. Designs must also recognize the safety considerations posed by persons with physical disabilities. The goal is to avoid personal injuries from stumbling, slipping, falling, running into objects, or being pushed into a dangerous situation.

Trespassers form a second consideration for pedestrian safety. Rail rights-of-way should be designed to be relatively inaccessible and warning signs should be used.

Security—Along with general pedestrian safety, security of individuals must also be considered. The problem is as much perceived security as it is any actual threat to persons using

the transit system. Designs should attempt to keep persons in full view of others and avoid solitary paths of movement in and around stations. The goal is to avoid security problems by keeping people together and within sight of one another. Proper use of CCTV systems with centralized security and communications bears consideration.

Fire—The primary source of transit fires is electrical systems, both in trackside power systems and onboard the cars themselves. The infrastructure must be able to evacuate trapped passengers quickly and safely and must allow access and safety for fire fighters. Designers are well advised to know their local fire safety codes and, in particular, NFPA 130, "Standard For Fixed Guideway Transit Systems." The goal is to avoid injury or loss of life due to fires occurring on the rail transit system.

2.3 DATA COLLECTION

2.3.1 General

A complete set of data and information is needed early in the rail corridor planning process. This data ranges from the demography of the human populations to be served to the physical characteristics that will govern engineering and design of the system. This section suggests the variety and scope of data to be collected and considered.

2.3.2 Demographic Data

Demography is "the statistical study of human populations, particularly with respect to size, density, distribution, and vital statistics." The beginning of the corridor analysis is to determine if there are enough people who are likely to utilize the corridor to justify an investment in rail transit. The study will seek to identify existing demand, and may be conducted as part of a larger effort to use rail transit as a tool to guide future development and to implement community land use policies. Sound data concerning the distribution, characteristics, and density of potential service populations are essential to estimating corridor demand.

The statistics must include where people live and where people work, as in most instances, the rail corridor will be connecting people to their workplaces. Trip origins may be generated by close-by high density housing, or by a more distant and dispersed market which arrives via park-and-ride facilities or on feeder bus systems.

Demographic data is also needed at the destination. For rail corridors, it is thought that most destinations will be defined by high density, temporary populations such as offices, commercial facilities, retail facilities, production facilities, transportation hubs, shopping areas, entertainment centers, recreational facilities, etc. People visiting these activities may be either workers or customers. For example, the temporary daily working population of New York's JFK Airport is 50,000 people, a substantial market in itself without considering customers.

The time of day that these populations congregate and disperse is critical to the corridor data. The primary task of the rail corridor will be the handling of the peak period passenger flows. The off-peak and reverse commute movements must also be estimated, since these supplemental markets are important to the overall economics of the corridor.

Vital statistics of the population are also important. The working population will have a different demand than the leisure population. Age distribution will affect demand and particularly future demand. Economic distribution will also affect demand.

2.3.3 Attitude Surveys

The attitudes of the current land owners and the residents of the communities through which the corridor passes will have a strong influence on the feasibility of a rail corridor. Survey data about these attitudes are important because they imply whether the project is a community effort, a development effort, or an unsupported engineering concept. Projects often fail to materialize due to the inability to resolve political differences.

The attitude surveys and observations must answer a number of questions:

- Is the rail corridor seen as improving mobility by local residents and businesses?
- Are there resistances to transportation system changes? If so, what are they?
- What are the perceived problems with the proposed transportation system?
- Will the political system support the changes called for by adoption of a rail transit corridor?
- How do attitudes vary between absentee owners, resident owners, and resident users?

A second set of objective data should be collected. This data supplements the community surveys and should include:

- Recent trends in land use density and land use classification
- Apparent reasons for change
- Probable life cycles of present and future land use developments

Opinion surveys must be interpreted with caution. What people say, how they feel, and what they eventually do to support or block a project are not always consistent. Taking surveys does serve the function of coupling the project and its planning team with the community. But objective data should always be utilized to assess the validity of subjective survey data.

2.3.4 Zoning Data

Land use zoning must be compatible with rail corridor development. The suitability of rail corridors is highly dependent on the timing and density of population movements and the presence of high density land occupancy.

Zoning maps and zoning levels help project future land use densities and weaknesses in the existing zoning plan. The zoning data must be evaluated from the standpoint of "what's practical." That is, how will zoning requirements change and will the market really support either the projected land use or the present zoning on the books?

2.3.5 Environmental Data

Various governmental requirements exist to control activities that may disrupt the environment. If the rail project will utilize Federal funds for its construction, the requirements for an Environmental Impact Statement (EIS) must be met. A project cannot be artificially divided into parts to avoid this requirement.

If federal funding is not used, state or local requirements must be met. Local requirements are often more stringent than the federal requirements.

The range of environmental investigation can include:

- Wetlands
- Endangered species
- Water quality
- Wildlife
- Air quality
- Hazardous substances (site clean-up)
- Public safety
- Public nuisances (noise, lighting, odor, vibration)

- Public convenience (transit times, detours, delays, accessibility)
- Rerouting of utilities and traffic
- Taking of property
- Archeology of historic sites
- Construction limits (duration, time of day, work sites)
- Construction nuisance
- Impact on commercial establishments
- Impact on property values

2.3.6 Geographic and Physical Data

Geographic and physical data is often available from previous surveys. Data sources include:

- Topographic maps
- Development maps
- Geologic data
- Climatic records
- Hydrological records
- Utility maps and records
- Railroad right-of-way maps
- Track and signal diagrams
- Other right-of-way maps

The physical characteristic data must be combined with demographic and transportation data to identify the physical obstructions and preferable routes for the natural flow of the transportation system. From this process, a set of possible corridor routes emerges to be evaluated.

2.3.7 Projection Data

The beginning of a rail corridor investigation should be a literature search of published population and economic growth projections. Public records and utility records are good sources of growth information.

The following points should be considered to assess the validity of the growth projections:

- What are the underlying assumptions?
- What assumptions are missing?
- What are the sources of the base data?
- Are the assumptions and base data adequate?
- Do the projections make sense?

Next, evaluate the projections themselves. Are they relevant to the rail corridor? What will be their effects?

Missing projection data must be developed. It is important that the corridor agency participate in development of projections so that other agencies' observations and knowledge are incorporated. A consensus is important; all parties should formally agree on the population and employment forecasts. Also, these forecasts should indicate a range of results (low, medium, and high) using appropriate statistical measures, such as means and standard deviations.

2.3.8 Current and Projected Transportation Demand

Accurate knowledge of current transportation patterns is indispensable to any rail corridor plan. The data desired is accurate origin-destination pairs by mode and by time of day.

Once the current transportation patterns are known, population, employment, and activity projections can be considered and the range of future demand forecast. The first transportation forecast assumes no changes in transportation infrastructure and forecasts the impacts of future increases in transportation demand.

If high density land use is present or projected, rail transit corridors should be considered. It is very important that once a rail corridor has been defined, it must be integrated into an overall regional or local area transportation plan. This plan must include highways, local roads, parking, and public transit.

2.4 CORRIDOR IDENTIFICATION

2.4.1 Rail Corridor Criteria

Within each given study area, specific corridors of transportation demand will exist. These corridors are defined by the transportation demand which arises from centers of economic and social activity such as business districts and their associated residential communities, schools, hospitals, and shopping and recreational areas. Transportation demand manifests itself as major traffic flows along the corridor between activity centers. The key point is to identify those corridors having sufficient ridership potential to justify consideration of the rail mode.

2.4.2 Transportation Demand

Corridor transportation needs should be considered within the context of both existing and projected demand. Existing demand will be evident from the current level of traffic on highways and transit routes within the corridor. Traffic congestion and/or heavy transit ridership point out areas where additional capacity is needed and where rail development may be feasible.

The forecasts produced by a metropolitan planning organization (MPO) and similar bodies should be considered in projecting future demand. These forecasts will provide an overall view of the area's anticipated transit demands. Corridor-specific studies should be conducted to accurately assess demand within each corridor. Study results must recognize and attempt to correct for the effects of data limitations, "built-in" software assumptions, and other circumstances which may be present.

Origin-destination studies can be undertaken to estimate future transportation demand in the identified corridors within an appropriate planning horizon.

2.4.3 Traffic Sources and Corridor Definition

A corridor will be generally defined by its major traffic flows. Key elements in refining the characteristics of a corridor are the identification and characterization of its major traffic sources. These passenger generators must be identified so that logical corridor end points and intermediate nodes can be determined, together with their connecting transportation links. Traffic flows can then be analyzed within the framework of this skeletal corridor defined by links and nodes.

2.4.4 Route Identification

Once identified, a corridor will broadly define the location of a proposed rail transit line within its boundaries. As corridor characteristics are analyzed, the rail line location will be further defined in terms of a general route or alignment. Characteristics defining a route may be the traffic demand pattern, existing transport facilities (rail lines, highways, power lines), or the natural topography. In some cases where a candidate route is delineated by existing or projected travel demand, there may not be an obvious physical route available.

These situations should be evaluated at an early stage so that their impact on project cost and feasibility may be determined.

In some situations, there will be two or more alternate (parallel) routes possible through all or part of the corridor. In these cases, an analysis must be conducted to rank candidate routes.

2.4.5 Constraints

Even at the earliest stages of a corridor study, certain constraints will be readily apparent. The initial feasibility survey of a rail corridor should attempt to identify as many of these constraints as possible. The available routes within a corridor may be constrained by both natural topography (hills, watercourses, wetlands, etc.) and the adjacent infrastructure (highways, urban development, etc.) In particular, constraints should be reviewed to identify "fatal flaws" as early as possible so that the list of feasible route alternatives may be initially ranked for later evaluation.

2.4.6 Land Availability

The availability of land suitable for rail transit development within a selected corridor may be limited. Often, land and right-of-way availability become the crucial issues in rail corridor development. The planning process should explore creative use of existing public and private rights-of-way to mitigate these problems.

The purchase of land to create a new transportation corridor where none exists is an expensive, time-consuming activity. It is a highly public endeavor requiring multiple review processes. As an alternative, it may be desirable to analyze the rail transit potential of existing transportation corridors, such as railroads, highway medians, utility rights-of-way, etc. The presence of a relatively inexpensive, existing right-of-way may make a rail project practical and economically justified, even if it is not among a region's most densely travelled corridors.

The use of existing rights-of-way is subject to two caveats: The conversion cost to rail transit use must be reasonable, and the project must service a meaningful level of transit demand.

Public agencies may also wish to preserve existing unused rights-of-way or actively assemble individual parcels into new corridors for future transportation use. Otherwise, these opportunities may be lost through uncoordinated land development.

2.5 CORRIDOR EVALUATION

2.5.1 Selection of Route Within a Given Corridor

Following the determination that a particular corridor justifies rail transit, the selection of the route to be utilized within the corridor is undertaken. The route selection process must recognize the differing characteristics of the various rail modes to some degree. If it has been determined that this corridor will be served as an extension of an existing system, then many of the design standards will be known at this point.

If the decision of which rail mode to use has not been made, the physical attributes of the corridor (such as right-of-way width, curvature, grades, street alignment vs. dedicated right-of-way, etc.) will influence the decision on the rail transit type to be used.

Another important activity early in the evaluation process, when federal (or other government) funds are used, is development of an Environmental Impact Statement (EIS). The EIS is a comprehensive and detailed study of the impacts of the rail corridor and alternatives to the route and mode chosen. The EIS process must be started early in project planning if implementation delays are to be avoided.

2.5.2 Convenience for Passengers

The most heavily weighted factor in the selection of a particular route within a corridor should be how well the line serves its potential passengers.

Passenger ridership studies and modal split analyses help determine how many passengers will ride a particular rail line. A route selection that maximizes the number of passengers attracted to the facility

indicates how well the public is served by the proposed route. One must also look at future growth tied to the zoning, future developments, regional planning, and other factors which affect where people work, where they live, and how they will travel.

Design criteria for rail transit projects differ from most railway engineering projects. Criteria such as shortest distance, least grade, curvature, ease of operation, and other factors are given far less weight in the design of an urban passenger line.

2.5.3 Land Availability

As development of urban and suburban areas continues, the identification of usable rights-of-way is a key item in the planning process. If the line is to serve any portion of suburban development, not only must land be available for the line itself, but equally important land must be available for the following:

- Station facilities
- Parking lots
- Pick-up and drop-off areas
- Shop facilities
- Substations and support facilities

The changing character of the work force over the past few decades has dramatically increased the proportion of rail riders requiring automobile parking space at the railhead.

2.5.4 Relationship to Highway and Street Network

The relationship of the location of stations to the highway network, and in particular, the freeway system and arterial road network, must be considered. If the purpose of the line is to serve a large area beyond the corridor itself, then the design of the station/highway interface may include modifications of the freeway interchanges to facilitate intermodal coordination.

The total travel time of the passenger is a very important consideration in route selection. However, this factor should not be calculated simply from one rail station to another; rather it must be calculated from the passenger's origin (home) to his/her destination (work, school, entertainment). Total travel time includes walking or driving, waiting, transfer, travel on bus and/or rail transit, walking, and elevators to final destination.

2.5.5 Central Business District Considerations

In the Central Business District (CBD) there are many factors that must be considered. An extremely important factor is how well the route is integrated with the passenger distribution system in the CBD. The alignment of the new system must also mesh with existing and proposed high rise development.

If there are other rail transit lines in the area, new stations should be located in a manner to allow ease of passenger transfer between systems. New stations should be directly connected to old stations if at all possible. If the CBD is, or will be, served by a local guided transport system it should complement the rail line—and they should not duplicate each other.

If buses and taxis are the prime means of distribution within the CBD, then the location and design of stations must be selected to facilitate transfer to these systems.

2.5.6 Urban Area—Interface with Local Neighborhoods

In the urban area, the route, type of construction (at-grade, aerial, underground), and selection of sites for stations, storage yards, and maintenance shops must conform with the nature and character of each neighborhood that the line serves.

Stations design should be integrated into the fabric of the individual neighborhood being served. From the engineering and operation standpoints, stations may be standardized but from aesthetic standpoint they should be assets and an integral part of the area. Properly done, the new stations will become the hubs in their local area and will attract development around them.

2.5.7 Joint Development of Transit Stations and Facilities

The location of a new transit station may attract private-sector development of stores, offices, and housing. The possibility of joint public-sector/private-sector investment should be considered when decisions concerning station location are being made. Such investments would offset portions of project construction costs and may be made through joint development of station/commercial complexes, establishment of benefit assessment districts, or other means negotiated between the parties.

Similarly, the use of air rights over rail storage yards and maintenance shops for commercial and residential use should be part of the basic planning of the line. Such basic considerations as additional spacing between yard tracks to allow later placement of columns for future construction allows such development much later, even though the precise nature of the development may not be predicted when the line is being built.

2.5.8 Protection of Property Values

In the suburban zone, the goal should be to locate the line in such a manner as to maintain property values—not reduce them. Stations must be located where large tracts of land are available for parking facilities. Both immediate and future parking needs should be thoroughly considered when site selection is being made.

In the urban zone, proper integration with existing distributor systems will reduce the need for large parking areas.

Location of traction power substations required by electrified lines must be handled carefully. If they cannot be located in industrial areas, careful attention must be given to the architecture of the structures in order that they appear to be part of the existing environment. They should blend with the appearance of adjacent buildings and maintain the property values of neighboring structures.

Where possible, substations may be integrated with passenger stations, shop facilities, or other project-related structures.

2.5.9 Factors Relating to Choice of Equipment

The type of equipment to be used must be determined before route evaluation is completed. In order to successfully achieve the mission of attracting passengers from automobiles to rail transit, the transit vehicle chosen must be fast, safe, and include a comfortable passenger environment. The cost of the vehicles is a major element in the economic evaluation of routes on a proposed new system.

The number of vehicles required on a system will depend not only on the length of a line but also on the actual operating speed, station dwell times, and other factors such as location of turnback facilities. When all of these factors have been considered, then a determination can be made of the type of equipment to be used within the corridor.

In the case of electrified lines, factors peculiar to this form of propulsion must be considered, such as the availability of electric power in the area. Depending on the type of electrification chosen (third rail or overhead wire) appropriate measures must be included to provide a safe environment.

In the case of internal combustion propulsion, factors such as fuel storage and handling, and the ventilation of tunnels and stations must be considered. Noise and fumes from idling equipment both during daytime layover in the vicinity of the CBD and during night hours at the urban or suburban terminals must be considered in terminal designs.

The equipment decision, the civil engineering standards for the route, and the service level to be achieved are all closely related. The following discussion gives a broad range of possibilities that can be considered.

2.5.9.1 Commuter Rail

Commuter rail services operate over trackage which is part of the general railroad system of transportation. As such, the rolling stock, signal equipment, and operating practices must be in accordance with all applicable government (e.g., Federal Railroad Administration) and Association of American Railroad standards. Commuter railroad operations, including associated terminals and shop facilities, will therefore require railroad-type rolling stock, large curve radii, low grades, and signaling systems compatible with main line railroad practice.

Passenger cars may utilize the single-level, bi-level or gallery configurations. Generally, multilevel cars will offer increased passenger capacity over single-level designs. Seating pitch and type (four-across vs. five-across) will also influence capacity.

Consideration should be given to use of as large a car as possible, consistent with capacity requirements, available physical clearances, and community preferences. Use of larger cars will keep the fleet size down and reduce many factors, such as:

- Cost of maintenance
- Length of station platforms
- Storage track requirements

If a desired extension requires tunneling (e.g., into the CBD), there is an immediate trade-off between the additional costs for tunneling for a larger car, versus the factors involved in a larger fleet. A limited area for a terminal station, on the other hand, may require use of high capacity cars to minimize required platform lengths. The trade-offs are unique for each situation, and should be evaluated to identify the most economic approach.

2.5.9.2 Rapid Transit

If the designated corridor has characteristics suggesting the need for a trunk line rapid transit system, the selection of such factors as car length, platform height, and door pattern affect the length of stations, the required running and station dwell time, and the number of cars in the fleet.

In turn, the selection of the route alignment may require cars that can negotiate small radius curves and steep grades. The height of the car becomes a factor in the cost of construction if extensive tunneling is involved. The weight of the car becomes a factor if extensive aerial structures are required.

The capacity of the cars, the size of the door openings, and the minimum spacing between trains strongly affects the design of the station platforms, staircases, escalators, and other station design elements relating to capacity.

2.5.9.3 Light Rail Transit (LRT)

Vehicles designed for use on lines which will include a combination private rights-of-way, aerial structures, tunnel, and running in public streets with automotive traffic must be designed to accommodate an additional series of criteria.

In order to negotiate curves required when turning corners in an existing street pattern, vehicles must be capable of negotiating extremely short radius curves. If the route under consideration has steep grades, these must also be accommodated.

Street running with automotive traffic requires that the braking rates and systems for vehicles in such service be capable of much shorter stops than other rail systems.

In order to obtain high productivity, many LRT lines utilize trains of several cars under control of one operator. The total train length must be determined such that the rear of a train stopping for a traffic light at one intersection will not interfere with traffic flow at adjacent intersections.

The design of stations within the city streets will be affected by, and will affect, the design of the car.

2.5.10 Choice of Route Within the Corridor

Basic route selection of all transportation facilities includes the factors of travel time, initial cost of construction, initial cost of locomotives and vehicles, operating costs over the life the system (life cycle cost of system), feasibility of construction and political acceptability. All of the factors enumerated above must be considered before the final evaluation is made.

2.6 SELECTION OF RAIL TRANSIT TECHNOLOGY

2.6.1 General

The central issue in the selection of the best-suited rail transit technology is the selection of the vehicle technology or type.

The functions of service goals and vehicle type/technology are closely interrelated. Service goals set the level of service frequency, transit time, station spacing, comfort levels, and amenities, as well as the nodes to be served. These, in turn, determine the power and propulsion requirements, station size, and vehicle configuration for expected loadings. Finally, the requirements for the vehicle type are reflected in the infrastructure (curvature, grade, speed capabilities), need for grade separation, and other design characteristics of the track and structure.

2.6.2 Vehicle Technology Types

There are four general types of rail transit technology that can be considered:

- Commuter Rail
- Heavy Rail
- Light Rail
- Automated People Movers

While each type has some flexibility in application, the technology must be compatible with the selected route alignment. As a result, from a technical standpoint, the selection of transit technology is interdependent with the choice and design of the route alignment.

2.6.3 Route Technical Constraints

The following route characteristics form the constraints that will influence the selection of the transit technology:

- *Exclusive Grade-Separated Right-of-Way*: This alignment represents an ideal situation for any rail technology. It is generally utilized when third-rail power collection is used and is a requirement when automated rail systems are employed, due to safety considerations. In addition, automated systems require fencing and should consider intrusion detection protection. Exclusive rights-of-way are desirable for higher operating speeds, regardless of the power supply or control systems.
- *Dedicated Grade-Level Right-of-Way*: Rail operators have often been located on dedicated rights-of-way with periodic crossings at grade for highways and pedestrians. This arrangement is typical of most of the U.S. railroad network and many transit operations. This configuration allows economy of development but incurs safety problems at street crossings and with trespassers.

- *Street Running or Non-Dedicated Right-of-Way*- Alignments which intermix rail vehicles with street traffic will generally prohibit commuter rail equipment due to size and braking distance requirements. Automatic systems are not suitable for street running due to the inability of their control systems to react to unsafe movement by automotive vehicles or pedestrians. Street running is well suited for light rail operations, and can offer advantages with respect to alignment flexibility and cost economies.
- *Curvature*: Commuter rail systems are typically limited to approximately 10 degrees of curvature, except in terminal areas. The other rail technologies can accommodate curvatures to 46 degrees (125-foot radius) and sharper; however, it is recommended that new construction limit curvature to approximately 23 degrees (250-foot radius) for light rail and 19 degrees (300-foot radius) for heavy rail. People mover systems can accommodate sharper curvature when short cars are utilized. Note that various features of car construction can materially influence the minimum radius curvature allowable. The table below illustrates typical minimum radius curvatures utilized on existing systems:

Typical Minimum Curvature Examples

Category	Mainline	Yards & Terminals
Commuter Rail	570 feet (10° maximum curvature)	300 feet (19° maximum curvature)
Heavy Rail	85-750 feet	85-300 feet
Light Rail	82-100 feet	82-100 feet
People Mover	230-328 feet	100 feet

Grade: Commuter rail, while using existing roadbeds in most cases, should utilize desirable grades of under 2 percent for mainline operations. Desirable maximum grades for heavy rail construction are approximately 3 percent. Light rail vehicles usually possess the ability to climb steeper grades than heavy rail equipment. New construction should reference existing operating properties to establish desirable grades. Care must be taken in considering propulsion methods and weather considerations in planning for gradients. A major criterion is vehicle braking performance on descending grades; systems utilizing automatic controls usually require that grades within 1,000 feet of stations be limited to 3 percent or less. See the following table for examples of existing systems.

Typical Maximum Gradient Examples

Category	Mainline	Exceptions
Commuter Rail	3 percent	—
Heavy Rail	6 percent	7 percent
Light Rail	5-6 percent	7 percent
People Mover	6 percent	8 percent

Speed: Typical design running speeds are 50 to 80 miles per hour. Commuter rail, if operating on joint use trackage, should be designed for speeds up to 79 miles per hour in wayside signal territory. It may be designed for higher speeds in cab signal or automatic train stop territory, as governed by FRA rules. Heavy rail vehicles, for the most part, are designed for fast acceleration/deceleration for throughput and frequent stops. Running speeds up to 65 mph are generally adequate. Light rail vehicles are also designed for fast acceleration/deceleration and may also be operated in non-exclusive rights-of-way or in street running with other vehicles. Typical light rail vehicles are designed for maximum speeds in the 50 to 65 miles per hour range. Automated systems for dense patronage in an urban environment have been designed for speeds up to 70 mph. Automated people movers also serve

dense patronage (such as at airports), but are designed for somewhat slower speeds, in the range of 25 mph to 50 mph. For each technology, desired speeds must be determined from station spacing, line geometry, braking capabilities, and the ability to attain and maintain vehicle design speeds.

Typical Maximum Speed Examples

Category	Maximum Speed
Commuter Rail	70-100 mph
Heavy Rail	50-80 mph
Light Rail	50-55 mph
People Mover	50-55 mph

Station Spacing: Criteria for planning station spacing should take into consideration land use patterns and population densities. Stations in central business districts and areas of high employment concentration will often require closer spacing than suburban stations. The availability of distribution and feeder systems will also affect station locations and spacing. Commuter rail stations are often several miles apart. Station spacings for heavy and light rail systems are progressively less. For automated people mover systems, spacing may be measured in the hundreds of feet, depending on the specific application.

Typical Station Spacing Examples

Category	Downtown	Outlying
Commuter Rail	1 Mile	5 Miles
Heavy Rail	0.5 Mile	1-2 Miles
Light Rail	Every Block or 2nd Block	0.5-1 Mile
People Mover	800-1500 Feet	0.5-1 Mile

2.6.4 Vehicle Technical Characteristics

Vehicle configuration is a variable of the technology selected, expected patronage loadings, and planned travel times. Commuter rail utilizes single vehicles for 80 to 185 passengers combined into trains of variable length. Commuter passengers usually require a seat because of the distances covered, limiting standee loads.

Heavy rail vehicles typically have a seating capacity of 40 to 80 passengers and can accommodate crush loads well in excess of 100 percent additional standees. Heavy rail operates in long trainsets with high platform loading/unloading capabilities and minimum headways.

Light rail employs single-vehicle seating capacities of approximately 50 to 85 passengers and utilizes three or four vehicle trainsets for peak operations. Because of operating philosophies and the street-level boarding/disembarking of the light rail vehicles, a 50 percent standing capacity is calculated for load analysis. When loads for light rail vehicles exceed this factor, a decision must be made as to accepting crush loads, adding more vehicles to trains, or by reducing headways. Each of these options must be looked at from a cost effectiveness standpoint.

Automated people mover systems are tailored to operate with either demand-sensitive or preset headways. Personal rapid transit cars may be designed for only six to ten passengers per vehicle, while cars in airport and urban service may be designed to accommodate 50 passengers or more per vehicle.

Systems can be planned for all persons seated, all standees, or a mix. A table showing the wide variety of vehicle designs follows:

Typical Vehicle Characteristics

Category	Seating Capacity	Maximum Capacity	Accel. Rate (mphps)	Decel. Rate (mphps)	Cars/Train
Commuter Rail	80-185	120-185	0.5	2.0	6-8
Heavy Rail	40-80	100-175	2.5-3.0	2.8-3.2	6-10
Light Rail	50-85	110-175	3.0	3.0-4.0	1-4
People Mover	30-50	75-160	2.2-3.0	2.5-3.0	1-8

2.6.5 Control Technical Characteristics

Signalling should not be viewed as a governing factor in the corridor selection process, but should become an outgrowth of the technology chosen, and must be appropriate for the speeds required and traffic density anticipated. Commuter rail, usually running on shared freight trackage, is best suited to operate with the system the railroad has in place. This allows quicker and less expensive start-ups. Heavy rail, by its nature, is sophisticated and modern-day systems are highly automated. Light rail, by its use of shared rights-of-way, does not need to be highly signalled. However, in tunnels and at higher speeds, a minimum of a wayside signal system should be used. With the trend of having light rail traveling down centers of boulevards and, in some cases, reverting to street running with automobiles, the signal system is often integrated with the automobile traffic signals. People movers require totally automated control systems, but generally have manually-operated backup controls for fault recovery, and for shop and yard movement.

Various types of control systems in use are listed here in order of increasing protection/automation:

LOS—Line of Sight
 MB—Manual Block
 ABS—Automatic Block System
 ATS—Automatic Train Stop
 ATP—Automatic Train Protection
 ATC—Automatic Train Control
 ATO—Automatic Train Operation

Control systems typically employed on the various rail transit modes are noted below:

Typical Control Characteristics

Category	LOS	MB	ABS	ATS	ATP	ATC	ATO
Commuter Rail	—	X	X	—	X	—	—
Heavy Rail	—	—	X	X	X	X	X
Light Rail	X	—	X	—	—	X	—
People Mover	—	—	—	—	—	X	X

2.6.6 Electric Traction Characteristics

The use of diesel power for new-start commuter operations is dictated by the joint use of trackage with diesel-powered freight operations and the capital cost of electrifying a railroad for commuter operations. Heavy rail, utilizing dedicated rights-of-way and subway operation, has commonly used a

third rail, collector strip, or overhead wire power distribution. The presence of grade crossings usually found in light rail operations will generally restrict the use of third-rail power collection and will normally require overhead contact or catenary wire. Power for automated people mover systems is always derived from the guideway. While these general guidelines apply, reference should be made to Chapter 33, Electrical Energy Utilization, for a more detailed discussion.

2.6.7 Safety

Safety considerations should be given high priority in the planning process for corridor selection. Factors that govern safety are:

- The level of signalization chosen
- Whether grade crossings are to be considered
- Whether the system operates on exclusive or shared right-of-way
- Type of power source
- Level of right-of-way securement

While the list is not complete, it should point out that each step of evaluating the technology should emphasize the safety level of the alternative considered.

2.7 REGIONAL TRANSPORTATION INTERFACES

Transportation interfaces are those points where transport systems or modes meet and require the passenger to change modes. The portrayal of interfacing between a rail transit corridor and other forms of transportation is described in this section.

2.7.1 Types of Interfaces

Interfaces of rail transit with other forms of transportation are basically as follows:

- Pedestrian Traffic or “Walk-Ins”
- Bicycles
- Automobile Traffic
 - Park-and-ride
 - Drop off passengers (Kiss-and-Ride)
 - Pick up passengers
 - Taxis
- Other Public Transit Systems
 - Buses and trolleys
 - Subway systems
 - Commuter rail systems
 - Inter-city passenger trains
 - Airports
 - People movers
 - Ferries

2.7.2 Typical Interfaces

Two basic types of stations and their respective interfacing are discussed below. The reader should also refer to Manual Chapter 6, Part 8 (Design Criteria for Railway Passenger Stations) and Chapter 14, Part 6 (Passenger Facilities) for additional information concerning stations. In this section, the emphasis will be on the relationship of rail transit corridors to other transportation modes and transportation systems.

Since no single system can meet all transportation needs, a set of systems exists. Ideally, an effective transportation plan combines these systems in an overall public policy. A level of service concept with a wide range of solutions is the key and requires interface coordination.

For the purpose of this discussion, a transportation system should be viewed not as technology, but as a means of moving people. The eventual success of the rail corridor will depend on this ability to smoothly interface and exchange passengers with other transportation systems.

The interfacing of two basic station types to their particular neighborhoods is described in the following paragraphs: the central business district (CBD) terminal and the suburban station. These two types of stations obviously have differing interface requirements, and generate passengers in different ways. For CBD stations, the interfaces with pedestrian traffic and high density transportation systems predominate. For outlying stations, distributor systems of buses and automobiles generate the majority of passengers.

2.7.3 Central Business District Stations

In the CBD station, pedestrians make up a large share of the arrivals and departures. Interfacing is primarily concerned with the location and flow characteristics of passageways in and out of the station. One problem is how to best direct the pedestrian traffic to bus stops, adjacent rail stations or waiting taxis. A second problem is to guide passengers out of the station to continue walking at street level. Ingress and egress of pedestrian traffic may either through buildings or via traditional sidewalk access.

Understanding the basic interfaces and realizing their importance in creating a desirable transport mix is essential for decision makers and station planners. The quality of the interface of rail transit with the other transport modes will have a large impact on rider's decisions regarding all public transit use.

Station interfaces, in general, must mesh with the local transportation network and be compatible with their neighborhoods.

2.7.4 Outlying or Distributor Stations

At outlying stations, park-and-ride passengers need dedicated, secure parking areas for a reasonable fee, a covered walkway through their lot, and an entrance and exit to parking. The parking entrance/exit must be coordinated with other station traffic and not hinder traffic on public streets.

Outlying stations must also accommodate kiss-and-ride auto traffic of two types, as drop-off traffic characteristics are not the same as for pick-up traffic. Drop-off traffic moves through the station do not need parking and should be routed back out into surrounding streets. Drop-off traffic should be separated from pick-up traffic where possible. Slowmoving traffic intending to pick-up people should have some short-term parking close to the station, be in view of people waiting in the station, and have a means of recirculating if there are no free parking places or their pick-up is not yet evident. Good coordination with the local traffic pattern is necessary.

The interface with bus lines is also important. Buses properly routed at the home end act as feeders to the corridor rail line. Buses can be utilized for collection and distribution, while the rail line is utilized for the line haul. Station design needs to handle bus traffic expeditiously. A good working relationship with bus operators during planning and design is essential.

Provision for secure storage of bicycles and pedestrian accessibility should also be considered.

2.8 CORRIDOR IMPLEMENTATION STRATEGIES

The preceding sections deal exclusively with conceptual engineering. At the conclusion of the conceptual phase, the feasibility of the project will be established so that a more definitive design of the proposed system can be developed in the next phase, preliminary engineering. At the end of the preliminary engineering activities, the project would be ready for implementation by the commitment of funding and the authorization of final, detailed design of all elements of the project.

The political and financial ramifications of transit corridor selection and route design must be considered concurrently with the preceding steps so that implementation of the system will proceed smoothly. Planning and design functions will be coordinated closely with the sponsor throughout the corridor selection process to insure accuracy of land acquisition needs and construction cost estimates.

Right-of-way acquisition is often the “make or break” factor for a proposed rail transit system and will, in some instances, govern the vertical location of the system. During the evaluation phase, the planning team must be constantly attuned to this important factor and be authoritative in assessments that sufficient right-of-way is available for the trackway, stations, sub-stations, yards, maintenance shops, and storage facilities. Wherever possible, viable alternate routes should be presented in addition to the preferred alignment. Costs and non-economic implications of each alternate approach should be clearly set forth for evaluation by public sector decision-makers. Very often legislation at one or more government levels is required to make the necessary land obtainable, and errors can be costly, or perhaps fatal, to the project.

Most rail transit systems are funded through a combination of sources such as local government, regional authorities, and state, provincial and federal governments. Here again, much care must be exercised during the evaluation process to provide accurate and defensible cost information to take to the supporting agencies, and sometimes the voting public, for approval of loans, grants, and bond issues. Major transit endeavors which overrun estimated construction costs and fail to achieve ridership and revenue targets alienate the general public and their legislators must be heavily involved in the evaluation phase of corridor and route selection activities. The time, cost, and effort associated with intense public involvement is a small price to pay for acceptance and approval of the proposed rail transit system by the general public and the involved agencies.

Proposed 1992 Manual Revisions To Chapter 13 - Environmental Engineering

Proposed revisions to Chapter 13, Part 5—Plant Utilities includes a rewrite of current Section 5.1 General Principles of Water Supply and addition of a Section 5.8 Cathodic Protection of Pipelines and Steel Storage Tanks.

A Section 5.8 on Cathodic Protection of Pipelines and Steel Storage Tanks currently exists in Chapter 13, Part 6—Corrosion Control. The rewritten Section being proposed is an update of those 1970 specifications, to be relocated to Part 5. A copy of proposed Section 5.8 may be obtained by writing to A.R.E.A. headquarters and enclosing \$2.00.

The rewritten Section 5.1 is to be retitled “Water Systems” and replaces 1970 specifications with current requirements for water supply, frequently citing American Water Works Association and other standards as well as environmental laws and considerations. An expanded subsection on tank design is included. The revised Section 5.1 follows:

5.1 WATER SYSTEMS

5.1.1 Quantity

The quantity of water from a source(s) should be adequate to supply the total water demand and provide a reasonable surplus for anticipated growth. An analysis of the elements making up the total water demand should be conducted. The analysis should include industrial uses, domestic uses, fire protection, etc. A source of water can be continuously adequate in quantity to satisfy demands or can be

converted from an intermittently inadequate source to a continuously adequate one by storing surplus water for use during periods of insufficiency.

The Insurance Services Office, New York, New York publishes a book entitled *Guide for Determination of Required Fire Flow* to aid in obtaining the required design flow capacity. Building codes often have requirements for domestic cases. Industrial cases can be obtained from an analysis of operations.

5.1.2 Quality

The quality should be satisfactory for the purposes intended. The various uses for water typically include drinking water, domestic, industrial, and fire fighting. Often the same source is used for all purposes.

The U.S. Environmental Protection Agency (EPA) regulates drinking water supplies. The Safe Drinking Water Act empowered the EPA to develop regulations on minimum water quality standards, testing requirements, and notification of users of poor-quality water. While most states enforce federal drinking water standards, many state and local agencies enforce their own, more stringent, drinking water standards that are subject to regular revision. Drinking water must be free of pathogenic organisms or other biological forms harmful to health. The water should not contain concentrations of chemicals that may be physiologically harmful.

Water should also be aesthetically pleasing, which generally means water should be cool, clear, colorless, odorless, and pleasant to taste. The water should not stain, form scale, nor be corrosive.

The quality requirements for industrial water generally are consistent with drinking water requirements, with certain exceptions. Additional treatment is sometimes necessary. Boiler make-up water and/or feed water should be low in hardness and dissolved minerals. Water for locomotive cooling systems should be low in mineral content and hardness, and should not be corrosive nor slime-forming. Battery water should be very low in dissolved minerals.

Manufacturers of equipment that uses water can provide specifications for the minimum quality required and outline the advantages of providing higher-quality water. Water treatment to achieve the minimum quality is common. Treatment equipment manufacturers and chemical companies selling treatment chemicals are good sources of information. Some consulting engineering firms can also provide information on water treatment.

5.1.3 Sources

Where water of suitable quality and in sufficient quantity can be purchased from an approved public water supply at reasonable cost, it is usually preferable. In other locations, the railroad may need to obtain other sources of supply. The alternative sources are surface water, groundwater, recycled water, or a combination of these sources. The source selected is a key factor in determining the need for purification, transmission, and storage facilities.

The majority of the water supplied in the U.S. is derived from surface water supplies. While groundwater can be used with a minimum of treatment such as disinfection, surface supplies typically require more treatment such as chemical coagulation, sedimentation, filtration, and disinfection. The additional treatment increases the capital and operating expenses for the water. Surface supplies often are much more variable as to available quality. This means that considerably larger facilities may be required to meet demand. The larger storage requirement increase the costs of providing water.

About one-fifth of the fresh water withdrawals in the U.S. are from groundwater resources. When available in sufficient quantity, groundwater is often the preferred source. Most is clear, cool, colorless, and unchanging from season to season. Underground supplies are generally of better bacterial quality and contain less organic matter than surface water, but may be more highly mineralized.

Groundwater sources also have some disadvantages. Groundwater typically costs more to pump than surface water. Exploration to define the groundwater quality and quantity can be very expensive. Some groundwaters are highly mineralized and contain large concentrations of sulfates, chloride, calcium, and magnesium, which are expensive to remove. In addition, groundwater can be highly contaminated from industrial, commercial, farming, and military activities. In some cases, if groundwater is overpumped, water quality can change significantly as water from other formations flows into the system.

Water recycled from previous uses is becoming more common, especially where large quantities of only moderate quality is needed. Water for mechanized washing of locomotive exteriors is a typical recycling use. The water can be recycled several times prior to eventual discharge when the quality deteriorates. In places where water is scarce, the cost of recycling may be less expensive than developing other sources of supply.

A combination of groundwater supplies, surface-water supplies, and recycling can sometimes be developed as a more reliable system rather than relying on any one source. Legal and physical constraints on amount of withdrawals, quality of recharge water, and land subsidence can affect which sources of supply can be used at any particular time.

5.1.4 Storage

5.1.4.1 General

The storage of water for potable usage, fire protection, industrial usage, or a combination of these may be necessary due to local water systems having inadequate pressure and/or volume or the absence of a local water system. Water storage can be accomplished using tanks and/or reservoirs.

5.1.4.2 Types

- A. Elevated tanks are tanks supported on a tower. Construction is usually steel, wood, or a combination.
- B. Standpipe tanks are flat-bottomed cylindrical tanks with a shell height greater than their diameter. Construction is usually steel or wire-wound prestressed concrete.
- C. Reservoirs can vary from dammed up creeks to flat-bottomed structures having a wall height less than any one of its surface dimensions. Construction can be of compacted earth, concrete, steel, wood, or plastics.

5.1.4.3 Design Standards

It is customary to contract the design and construction of elevated and standpipe storage tanks to outside companies competent in these fields. The tank design, including foundation and erection, should conform to the appropriate American Water Works Association Standards, as listed below.

D100-84 Welded Steel Tanks for Water Storage

D103-87 Factory-Coated Bolted Steel Tanks for Water Storage

D110-86 Wire-Wound Circular Prestressed Concrete Water Tanks

D120-84 Thermosetting Fiberglass-Reinforced Plastic Tanks

For eastern reservoirs, the U.S. Department of the Interior, Bureau of Reclamations publication entitled "Design of Small Dams" is recommended.

5.1.4.4 Design Considerations

- A. Volume should be based on operating/equalizing storage, fire reserve, and emergency reserve. Operating/equalizing storage should be determined from hourly demands for the maximum day and the existing or proposed supply rate. The fire reserve is a function of the fire duration and flow rate necessary to provide adequate coverage. The duration and flow rate may be set by

local ordinance or the Company's insurance carrier. Emergency reserve is dependent on the length of time the facility can function without water supply. Duration of required maintenance and equipment replacement should be considered in emergency reserve.

- B. Storage elevation must be high enough to provide adequate pressure throughout the distribution system. Booster pumps and fire pumps can be used to increase pressure and reduce storage elevation. A complete hydraulic analysis of the system should be conducted to ensure necessary operating pressures and volumes.
- C. Snow loadings should be considered based on local conditions and codes.
- D. Special wind loading may be appropriate based on local conditions and codes.
- E. Earthquake design should be considered based on seismic zones per Appendix A of AWWA D100-84.

5.1.4.5 Tank Painting

Water storage tanks should be painted to prevent interior and exterior corrosion. Interior paints for tanks storing potable water should not contain toxic substances in amounts that can create health hazards. AWWA D102-78 should be followed.

5.1.4.6 Inspection and Maintenance

All water storage tanks should be thoroughly inspected at intervals of not more than five years. It is recommended that tank inspections and repairs conform to AWWA D101-53/R86.

5.1.5 Water Treatment

5.1.5.1 General

For most uses of water, some form of chemical treatment is necessary, and it must be based on the study of the particular requirement.

5.1.5.2 Potable

Generally, drinking water should be obtained from municipal sources that have been pre-treated. However, when water is obtained from other sources such as streams or wells, it is necessary to disinfect and treat the water according to the standards of the Safe Drinking Water Act referred to in Sections 5.1.2 and 5.1.8.5-b or to the appropriate state or local standards.

5.1.5.3 Industrial Water

Adequate quantity and quality of water is necessary for on-site uses such as boiler feed water, cooling water and fire protection.

For boiler water treatment, the primary contaminants to be removed are calcium and magnesium which cause hard water scale inside the boiler. This can best be accomplished with a modern ion-exchange water softening system. Other contaminants such as silica, alumina, and iron can best be treated internally in the boiler after consulting with the boiler chemical supplier.

5.1.5.4 Water Treatment Wastes

Railroad facilities generally discharge their water treatment wastes either into a stream or into a municipal water treatment facility. Each will have separate and varying requirements as to waste quality such as the level of suspended solids, oil and grease and other contaminants. It is necessary to check with the federal (EPA), state, and local regulatory agencies to determine the appropriate discharge requirements for the particular facility. Refer to Chapter 13, Section 1.3 for further detail.

General sources of contaminants are washing facilities such as locomotive washing, car clean-out facilities, and general shop maintenance cleanup. Cooling water from either locomotive radiators or from stationary cooling towers is also a potential contaminant. Locomotive fueling facilities are a major

source of oil contamination. In addition, surface water run-off can be a significant contributor to wastewater contamination.

REFERENCE: AMERICAN WATERWORKS ASSOCIATION STANDARD MANUALS

The AWWA's manuals are a complete up-to-date waterworks standard for your reference in water projects. They are available from:

AMERICAN WATERWORKS ASSOCIATION
666 W. QUINCY AVENUE
DENVER, CO 80235

5.1.6 Cooling Water Reclamation

Some cooling water treating chemicals are toxic; discharge to streams or sewers is prohibited. Typical chemicals used for this purpose (such as borates, nitrites, nitrates, and to a much lesser extent, chromates) are used for corrosion protection. Recycling of cooling water has proven economical for several railroads. Cooling water drained from radiators should be filtered to remove insoluble solids. Oil is generally present and should also be separated. The coolant should be brought up to proper strength prior to reuse. Cooling water additives deplete at varying rates; check with the additive supplier for proper dosages.

In addition, large amounts of cooling water are often used in cooling compressors for hump retarders, etc. In many cases, this water is done through cooling which wastes water and adds to sewer discharge. This water should be recycled. Treatment with a corrosion inhibitor package is required when recycling.

5.1.7 Water Analysis

5.1.7.1 General

Water analysis falls into two categories: 1) analyses performed for industrial water usage; and 2) analyses performed for drinking water purposes. When analyzing water samples, it is necessary to determine the presence of various substances which may be found in relatively small amounts. For industrial water usage, the results of water analyses are usually expressed in parts per million (ppm), otherwise known as milligrams per liter (mg/l). As an alternative, the results can be reported in grains per gallon (gpg). One gpg equals 17.1 ppm. For drinking water usage, results are usually reported in parts per million, but for substances with very low allowable limits, concentrations may be expressed in parts per billion (ppb) or micrograms per liter ($\mu\text{g/l}$).

5.1.7.2 Analytical Requirements

Analytical procedures for industrial and drinking water purposes should be conducted in accordance with standards as set forth in one or more of the following:

- A. "Standard Methods for the Examination of Water and Waste Water," American Public Health Association, current ed.
- B. "Methods For Chemical Analysis of Water and Wastes," EPA Environmental Monitoring and Support Laboratory, March 1979.
- C. "Annual Books of ASTM Standards," Volumes 11.01 and 11.02, American Society for Testing & Materials.
- D. "Guidelines Establishing Test Procedures For Analysis of Pollutants Under the Clean Water Act," 40 CFR Part 136.

In addition, drinking water analyses should include requirements as found in 40 CFR Part 141, "National Primary Drinking Water Regulations." It is also advisable to consult with local and state Health Departments for additional requirements.

5.1.8 Water Distribution

5.1.8.1 General

Water distribution systems are ordinarily designed to adequately satisfy the water requirements of a facility for potable, industrial, and fire fighting purposes. The system should be capable of meeting the demands placed on it at all times and at satisfactory pressures. The main elements are pipe systems, pumping stations, storage facilities, and other appurtenances.

Distribution systems are generally classified as branch systems with dead-end branches feeding from the main supply line, or grid/loop systems which have all supply and feeder lines linked together.

Loop systems have the advantage of providing flow from more than one direction as well as allowing maintenance and emergency repairs without total system shutdown. This type of system is recommended for large shop facilities and/or where uninterrupted service is necessary.

Branch systems are typical for small facilities and single buildings where loop systems are economically unjustified.

5.1.8.2 Piping Systems

A. Piping should be installed per appropriate AWWA specifications as follows:

C600-87	Installation of Ductile-Iron Mains and Appurtenances.
C602-83	Cement-Mortar Lining of Water Pipelines 4-Inch (100 mm) and Larger—In Place.
C606-87	Grooved and Shouldered Joints.

B. Pipe and fittings should meet the following AWWA specifications:

C104/A21.4-85	American National Standard for Cement Mortar Lining for Ductile-Iron Pipe and Fittings for Water.
C105/A21.5-82	American National Standard for Polyethylene Encasement for Ductile-Iron Piping for Water and Other Liquids.
C110/A21.10-87	Ductile-Iron and Gray-Iron Fittings, 3-Inch through 48-Inch, for Water and Other Liquids.
C111/A21.11-85	Rubber-Gasket Joints for Ductile-Iron and Gray-Iron Pressure Pipe and Fittings.
C115/A21.15-83.	American National Standard for Flanged Ductile-Iron and Gray-Iron Pipe with Threaded Flanges.
C150/A21.50-81 (R86)	American National Standard For Thickness Design of Ductile-Iron Pipe.
C151/A21.51-86	American National Standard for Ductile-Iron Pipe Centrifugally Cast in Metal Molds or Sand-Lined Molds for Water or Other Liquids.
C153/A21.53.84	American National Standard for Ductile-Iron Compact Fittings, 3-Inch through 12-Inch (75 mm through 300 mm), for Water and Other Liquids.
C200-86	Steel Water Pipe 6-Inch & Larger.
C203-86	Coal-Tar Protective Coatings & Linings for Steel Water Pipelines Enamel and Tape—Hot Applied.

C205-85	Cement-Mortar Protective Lining & Coatings for Steel Water Pipe—4 Inch and Larger—Shop Applied.
C-206-82	Field Welding of Steel Water Pipe.
C-207-86	Steel Pipe Flanges for Waterworks Service, Sizes 4 Inch Through 144 Inch.
C-208-83	Dimensions For Fabricated Steel Water Pipe Fittings.
C209-84	Cold-Applied Tape Coatings for the Exterior of Special Sections. Connections & Fittings for Steel Water Pipelines.
C210-84	Liquid Epoxy Coating Systems for the Interior & Exterior of Steel Water Pipelines.
C213-85	Fusion-Bonded Epoxy Coating for the Interior & Exterior of Steel Water Pipelines
C214-83	Tape Coating Systems for the Exterior of Steel Water Pipelines.
C300-82	Reinforced Concrete Pressure Pipe, Steel Cylinder Type, for Water and Other Liquids.
C301-84	Prestressed Concrete Pressure Pipe, Steel-Cylinder Type, for Water and Other Liquids.
C302-87	Reinforced Concrete Pressure Pipe, Non-cylinder Type, for Water and Other Liquids.
C303-87	Reinforced Concrete Pressure Pipe-Steel Cylinder Type, Pretensioned, for Water and Other Liquids.
C900-81	Polyvinyl Chloride (PVC) Pressure Pipe, 4 Inch Through 12 Inch, for Water.
C901-78	Polyethylene (PE) Pressure Pipe, Tubing, and Fittings, 1/2 Inch Through 3 Inch, for Water.
C902-78	Polybutylene (PB) Pressure Pipe, Tubing, and Fittings, 1/2 Inch Through 3 Inch for Water.
C950-81	Glass-Fiber-Reinforced Thermosetting Resin Pressure Pipe.

The pipe material chosen should taken into account existing soil conditions, as most railroad yards consist of cinder fill and consequently are very corrosive.

- C. Installation of new pipe lines should include disinfection per AWWA C651-86, "Disinfecting Water Mains."

5.1.8.3 Pumping Stations

Pumping stations in water systems usually serve the purposes of lifting water from its source to treatment facilities or directly to the distribution system, and of boosting water pressure for fire fighting or other purposes. There are a large number of pump types and variations used in water supply. The most frequently used are centrifugal pumps. It is recommended that pump design be referenced to a civil engineering or hydraulic handbook. For vertical turbine pumps, AWWA E101-77/(R82) is recommended.

5.1.8.4 Storage

Refer to Section 5.1.4 for design and other details. For disinfection of water storage facilities, refer to AWWA C652-86.

5.1.8.5 Appurtenances

- A. Fire hydrant location and size are dependent on local ordinances and should be designed to be compatible with local fire fighting equipment (i.e., pipe threads, etc.). Local ordinances may also require pressure and flow testing of hydrants on a periodic basis. Hydrants should also conform to AWWA 502-85 Dry-Barrel Fire Hydrants and AWWA 503-82, "Wet-Barrel Fire Hydrants."
- B. Public Law 93-523, "Safe Drinking Water Act of 1974," requires all public water systems to institute a cross connection control program that would eliminate the possible drinking water contamination caused by negative and/or pressure losses in water distribution systems. Devices used to eliminate these cross-connections (commonly called backflow preventers) range from hose bib vacuum breakers to large diameter double check reduced pressure valves. Good references of cross-connection control are AWWA handbooks "Cross-Connection and Backflow Prevention" (1974) and "Recommended Practice for Backflow Prevention and Cross-Connection Control (1970)." These devices must meet one or more of the following standards:

AWWA C506-78/(R83) Backflow Prevention Devices, Reduced Pressure Principle, and Double Check Valve Types.

ASSE 1001 Atmospheric Type Vacuum Breakers.

ASSE 1011 Hose Connection Vacuum Breakers.

ASSE 1020 Pressure Type Vacuum Breakers.

ASSE 1024 Dual Check Type Backflow Preventer.

ASSE 1013 Reduced Pressure Principle Back Pressure Backflow Preventers.

ASSE 1015 Double Check Valve Type Back Pressure Backflow Preventers.

Proposed 1992 Manual Revisions To Chapter 15 - Steel Structures

Various changes are proposed to specifications in Parts 2, 3, 4, 6, 7 and 9 of Chapter 15. The specific changes are as follows:

PART 2—Design-High Strength Steels

From Tables 2.2 1A and 2.2 1B (page 15-2-3) remove A441 steel requirements.

PART 3—Fabrication

In Article 3.1.6 (d) (page 15-3-3) remove in the first sentence reference to ASTM A440 steel.

PART 4—Erection

1. Revise paragraph 4.6(b) (page 15-4-2) to read:

- (b) The Contractor shall prepare erection procedures and submit them for approval by the Company.

2. Revise paragraph 4.7(a) (page 15-4-3) to read:

- (a) Where the contract indicates that materials are to be furnished by the Company, the Contractor shall receive all such materials at the place and under the terms specified in the contract documents.

PART 6—MOVABLE BRIDGES

1. In paragraph 6.5.37.10.4 (b) (page 15-6-38.8) delete reference to A669 steel.

2. Revise paragraph 6.5.37.10.4 (c) (page 15-6-38.8) to read:

- (c) Stainless steel tubing shall conform to the following ASTM specifications:

A 269—Grades TP304 or TP316

A 789

PART 7—EXISTING BRIDGES

Replace paragraph 7.3.4.2 Fatigue (page 15-7-11) with the following:

7.3.4.2 Fatigue (See also Commentary Art. 9.7.3.4.2)

- (a) Welded or rolled members and welded and high strength bolted connections subject to repeated fluctuations of stress, fatigue requirements of Arts. 1.3.13 or 2.3.1 shall be considered.
- (b) Members with riveted or bolted connections with low slip resistance, subject to repeated stress fluctuations: the requirements of Category D of Arts. 1.3.13 and 2.3.1 shall be considered. Where the Engineer can verify that the fasteners are tight and have developed a normal level of clamping force fatigue Category C may be used provided the Root-Mean-Cube (RMC) stress range has not and will not exceed 12 ksi. If Category C is used, the fatigue line on a stress range vs predicted cycles to failure plot should be extended down to the Constant Amplitude Fatigue Limit predicted by Category D. In other words, the value of the constant amplitude fatigue limit is to be Category D in all cases (see Figure 9.7.3.4.2B).
- (c) Riveted and bolted connections and members that do not satisfy the requirements of Art. 7.3.4.2(b): these requirements may be waived at the discretion of the Engineer if the connections or members will retain their structural adequacy if one of the elements cracks and if the Root-Mean-Cube (RMC) stress range is less than 12 ksi. The connection and/or member of span must have adequate capacity to carry the redistributed load, and a frequency of inspection which will permit timely discovery of any local failure and need for corrective action. This paragraph shall not be applied if there is insufficient and/or inadequate lateral bracing of the potentially cracked member.
- (d) Wrought iron riveted connections shall be considered to have Category E fatigue strength.
- (e) Eyebars and pinplates subject to repeated fluctuations of stress: the requirements of fatigue Category E of Arts. 1.3.13 and 2.3.1, for the nominal stresses acting on the net section of the eyebar head or pinplate, shall be considered.
- (f) Where the thickness of a component has been reduced by corrosion to less than 50% of its original thickness, a Category E detail shall be assumed to exist at that location.
- (g) Where the actual stress cycles can be estimated from traffic records, an effective stress range can be determined for the total number of variable stress cycles,

$$N_v, \text{ as } S_{Re} = \alpha (\sum \gamma_i S_{Ri})^{1/3}.$$

S_{Re} and N_v for the applicable design detail must be less than fatigue strength curves shown in Fig. 9.7.3.4.2A. If more than 0.1% of the stress ranges have exceeded, or will exceed the constant amplitude fatigue limit for that detail, the constant amplitude fatigue limit shall not be

used and the appropriate fatigue line shall be extended (see Fig. 9.7.3.4.2B). The appropriate value of α shall be taken from Table 9.1.3.13A unless an appropriate analysis provides a more accurate estimate. γ_i and S_{R_i} are the ratio of S_{R_i} to the number of occurrences of cyclic stress. N_v and corresponding stress range of the estimated traffic, α is defined in Art. 9.1.3.13.

PART 9—COMMENTARY AND BIBLIOGRAPHY

1. Replace paragraph 9.7.3.4.2 Fatigue (page 15-9-33) with the following:

9.7.3.4.2 Fatigue

The intent of evaluating a structure for fatigue in Art. 7.3.4.2 is to minimize the probability of failure as a result of crack growth. This primarily affects the maximum service life that the structure is designed for. If a reduced life is acceptable, higher loads are permissible providing the serviceability is not impaired throughout the shortened useful life.

Welded structures do not have the inherent redundancy of non-corroded riveted construction. Hence the consequences of fatigue crack growth are more serious for most welded connections and members than for riveted structures with built-up sections. The internal component redundancy of riveted members has generally permitted part of the member to fail and redistribute its load elsewhere.

Experience with welded highway bridges that have experienced fatigue cracking has demonstrated that the members usually fail before the crack is discovered. (40, 41). As a result it appears prudent to use the requirements of Arts. 1.3.13 and 2.3.1 when rating welded bridge members. High strength bolted joints provide very high fatigue resistance.

The fatigue resistance of members with riveted and other mechanically fastened connections with low slip resistance is defined by Category D as a result of review of available test data (42, 51, 52). Referring to Figure 9.7.3.4.2B, it is apparent that nearly all test data on riveted joints with normal levels of clamping force fall to the right of the line defined by Category C between 7 and 12 ksi. The existing test data (51, 52) shows failures at a high number of cycles below the constant stress range fatigue limit for Category C, but above the constant stress range fatigue limit value for Category D. Hence, any evaluation using Category C must extend past 10 ksi, on to 7 ksi. For stress ranges above 12 ksi the test results for riveted connections seen in railroad bridge construction fall to the right of the line defining Category D.

It is reasonable to permit a higher fatigue stress range for Root-Mean-Cube (RMC) stress ranges below 12 ksi if it can be demonstrated that the connection or member in question has tight riveted joints.

This discretion has been left to the Engineer dependent on his verifying the tightness of the rivets or bolts and the adequacy of the clamping force.

For riveted construction where the members are fabricated from multiple elements, the immediate consequences of fatigue cracking may not be as serious as in welded structures. Riveted construction often has built-up members and connections, so that if one element fails, there is normally sufficient capacity and redundancy to permit the load to be redistributed and the members will usually survive long enough for the crack to be detected by routine inspection thereby permitting corrective action before more serious damage develops. If no immediate repair action is to be taken, the probable time between first detectable cracking and uncontrolled propagation should be taken in account when setting up inspection frequency. Where the constant amplitude stress range exceeds 12 ksi, test results indicate that not much time exists between easily detectable cracking and member failure.

Art. 7.3.4.2(c) permits waiver of the fatigue provisions when the Engineer can show that the structure has an adequate level of redundancy, so that should cracking develop it can be accommodated. A restriction ensuring that sufficient lateral resistance is provided by bracing or diaphragms to ensure that existing crack tips will not be subjected to unaccounted secondary stresses is consistent with the failure experienced in tests (52).

Wrought iron riveted connections exhibit a fatigue strength represented by Category E (51, 52).

Test Results (51, 52) indicate that severe corrosion may lead to the initiation of cracks. If the thickness of a component is reduced by 50% the location is best categorized by Category E. Until more conclusive test results are available, no advice can be given in this Manual on sections with less than 50% loss of thickness.

For eyebars and pin plates the critical section is at the pin hole normal to the applied load. Several studies have indicated that the stress concentration factor at such a location is in excess of 4 (42, 43). Category E is intended to provide a conservative estimate of fatigue resistance at such connections. Particular attention should be given to any forge seams or other unusual flaw-like conditions that may exist at the bore of the eyebar normal to the applied load.

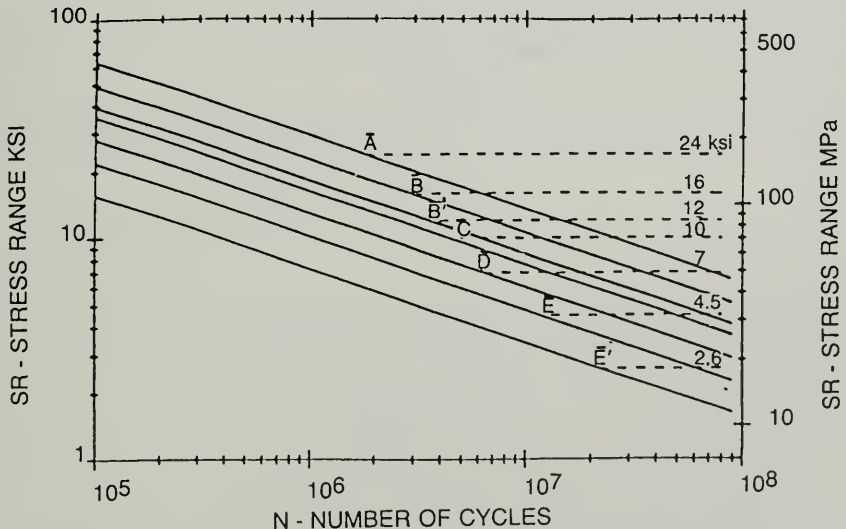
Suitable analytical and/or experimental studies may show that a lower stress concentration exists if pin fit and the component geometry are favourable. If the stress concentration factor is less than 4, design category D can be used to assess fatigue resistance.

When the actual stress cycles can be estimated from known traffic, the total variable stress cycles can be estimated and the effective stress range calculated as

$$S_{Re} = \alpha (\sum \gamma_i S_{Ri}^3)^{1/3} \quad (42, 45).$$

The resulting coordinates can be compared with Fig. 9.7.3.4.2A for the applicable design detail. The limit of 0.1% of stress ranges being sufficient to eliminate the existence of the Constant Amplitude Fatigue Limit is approximate and is based upon a small number of tests (53). The values of α for various spans and member classification are tabulated in Table 9.1.2.13A. The factor γ_i is the ratio of the number of occurrences of S_{Ri} to the total number of occurrences of cyclic stress, N_v .

2. Replace Figure 9.7.3.4.2 (page 15-9-34) with the following two Figures 9.7.3.4.2A and 9.7.3.4.2B:



Constant Amplitude Fatigue Limit

S_R -N Curves

Figure 9.7.3.4.2A

General Equation:

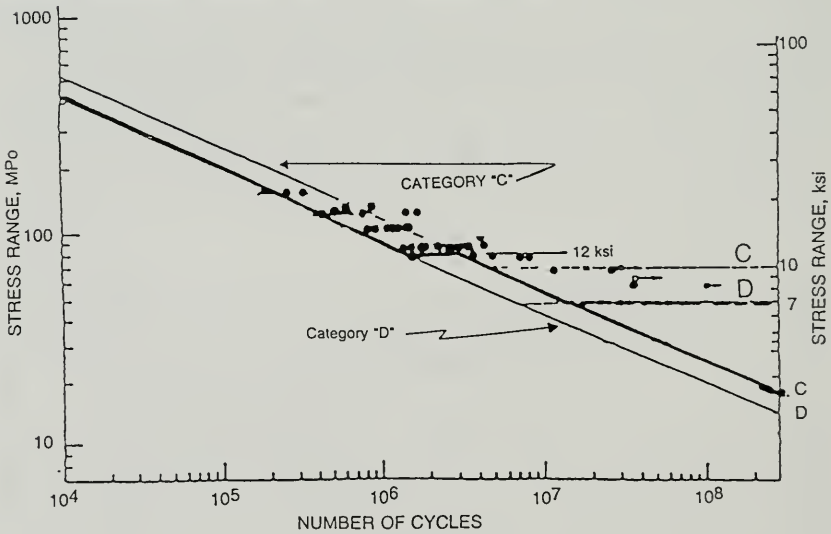
$$N = A + S_R^{-3.0}$$

N = estimated minimum number of cycles to failure

S_R = allowable stress range, ksi

A = constant as listed below

Category	Constant A
A	2.5×10^{10}
B	1.2×10^{10}
B'	6.1×10^9
C	4.4×10^9
D	2.2×10^9
E	1.1×10^9
E'	3.9×10^8



Riveted Members

Figure 9.7.3.4.2B

3. Add items 49 to 52 as follows to the Bibliography (page 15-9-43).

49. Evaluation of Fatigue Tests and Design Criteria on Welded Details, P. B. Keating and J. W. Fisher, NCHRP Report 286, 1986.

50. Fatigue Strength of Weathered and Deteriorated Riveted Members, J.M.M. Out, J. W. Fisher and B. T. Yen, Final Report DOT/OST/P-34/85/016, U.S. Dept. of Transportation, Oct. 1984.

51. Fatigue and Fracture Evaluation for Rating Riveted Bridges, J. W. Fisher, B. T. Yen, D. Wang and J. E. Mann. NCHRP Report 302, Dec. 1987.
52. Steel Bridge Members under variable amplitude long life fatigue loading, J. W. Fisher, D. Mertz and A. Zhong, NCHRP Report 267 (1983).

Proposed 1992 Manual Revisions To Chapter 16 - Economics of Plant Equipment & Operations

Proposed revisions to Chapter 16 include a rewrite of Part 2, Section 2.1 Resistance to Movement and Part 5 Location of Auxiliary Facilities.

Substantive changes to Section 2.1 are improvements to the Davis Equation for today's equipment, including radial trucks. Also, values for train resistance in tunnels have been developed and the effects of rail lubrication, track quality and concrete ties, articulated cars and other types of equipment on train resistance are discussed.

Part 5 is to be retitled Economics and Location of Defect Detector Systems. The current material in Part 5 on Hotbox Detectors was written in 1970. The new material proposed will address other types of detectors as well as hot bearing types.

The proposed new Section 2.1 and Part 5 follow:

2.1 RESISTANCE TO MOVEMENT

2.1.1 Level Tangent Track

A railway vehicle moving upon level, tangent track, in still air and at a constant speed encounters certain resistances that must be overcome by the tractive effort of the locomotive.

These resistances include: (1) Rolling friction between wheel and rail. This can be considered a constant for a given quality of track. (2) Bearing resistance. This varies with the weight on each axle and, at low speed, the type, design and lubrication of the bearing. (3) Train dynamic losses. These include flange effects which are associated with lateral motion and the resulting friction and impact of the wheel flanges against the gage side of the rail. They vary with speed, rail alignment, track quality, the surface condition of the rail under load, the horizontal contour of the railhead, contour and condition of the wheel tread, and the tracking effect of the trucks. Also there are miscellaneous losses due to sway, concussion, buffing and slack-action. (4) Air resistance, which varies directly with the cross-sectional area of the vehicle, its length and shape, and the square of its speed. It is also influenced by zones of turbulence related to shape.

Various tests made over the years have shown that the resistance to train movement can be determined using an empirical expression of the following form:

$$R = A + BV + CDV^2$$

where: R = train resistance in lbs
 A = rolling resistance component independent of train speed
 B = coefficient used to define train resistance dependent on train speed
 C = streamlining coefficient used to define train resistance dependent on the square of the train speed
 D = aerodynamic coefficient or polynomial function used to further define train resistance, often combined with C
 V = train speed in mph

The predominant but not exclusive contributors to the various coefficients are as follows:

A	B	C & D
—Journal resistance	—Flange friction	—Head-end wind pressure
—Rolling resistance	—Flange impact	—Skin friction on the side of the train
—Track resistance	—Rolling resistance wheel/rail —Wave action of the rail	—Rear drag —Turbulence between cars —Yaw angle of wind tunnels

2.1.2 Davis Formula—Historic Development

In 1926, W. J. Davis (1) proposed an empirical formula for computing “Tractive Resistance of Electric Locomotives and Cars” moving on straight and level track. His proposed values for the coefficients A, B and CD shown above were as follows:

$$A = 1.3 + \frac{29}{W}$$

$$B = 0.03 \text{ for locomotives or } 0.045 \text{ for freight cars, and}$$

$$CD = \frac{Ca}{WN}$$

where: R = Train resistance in lb/ton
 W = Axle weight in tons per axle of locomotive or car
 N = Number of axles
 a = The cross-sectional area of the locomotive or car in square feet
 C = The streamlining coefficient

C was given various values, e.g., 0.0024 for lead locomotives or 0.0005 for trailing locomotives and freight cars.

The equation which Davis proposed thus became (for freight cars):

$$R = 1.3 + \frac{29}{W} + 0.045V + \frac{0.0005aV^2}{WN}$$

The original Davis formula has given satisfactory results for older equipment with journal bearings within a speed range between 5 and 40 mph. Tuthill (2) and Totten (3) had adjusted this formula for higher speeds. However, roller bearings, increased dimensions and heavier loading of freight cars, the much higher operating speeds of freight trains, and changes in the track structure have made it desirable to modify the constants in the Davis equation.

Tests in the 1940's and 1950's showed improved results using the following modified Davis Formula (4):

$$R = 0.6 + \frac{20}{W} + 0.01V + \frac{KV^2}{WN}$$

where: R = resistance in pounds per ton
W = weight per axle in tons
N = number of axles
V = speed in miles per hour
K = combined air resistance coefficient:
0.076 for conventional equipment
0.16 for piggyback
0.0935 for containers

2.1.3 Recent Developments

The original train resistance formula has been retained as to form, but over the years different coefficients have been developed to reflect changes such as higher speeds, more modern equipment, and today's track and truck designs.

The 1990 Canadian National version of the train resistance formula (6) is presented below. When used with the coefficients shown (many of which have been developed in dynamometer car tests), the formula has given reliable results in train performance calculator programs or similar applications.

$$R_r = 1.5 + \frac{18N}{W} + 0.03V + \frac{CaV^2}{10000W}$$

where: R_r = the rolling resistance of vehicle in lb/ton
N = Number of axles
W = Total weight in tons of locomotive or car
V = Velocity of train in miles per hour
C = The Canadian National streamlining coefficient, and
a = The cross-sectional area of the locomotive or car in square feet

The following table shows the range of values for the C coefficient for various kinds of equipment. Note that these values for C are scaled for use with the Canadian National formula only.

Table of Values of C Coefficient (7)
For Use With Canadian National Train Resistance Formula Only

Degree of Streamlining	Equipment	C Coefficient	
		Leading Eqpt.	Trailing Eqpt.
Nil 1.	Open auto transporter	—	12.3
Nil 2.	Freight locomotive	24.0	5.5
	Mixed consist of freight cars	—	5.0
Low 3.	RDC	19.0	4.0
Low 4.	Conventional passenger incl. loco.	19.0	3.5
Med 5.		14.0	3.0
Med 6.		10.0	2.6
High 7.	High speed passenger	7.6	2.3
High 8.	Maximum possible streamlining	7.0	2.0

When certain types of cars predominate in a train more accurate resistance values for such a train can be obtained by using C coefficients from the following table. The table shows in more detail recommended Canadian National values for C and cross-sectional areas for the various equipment types.

**Table of Values of C Coefficient and Areas
for Freight and Passenger Equipment
For Use with Canadian National Train Resistance Formula Only (8)**

Type of Equipment	C Coefficient	Area (sf)
Box Car	4.9	140
Bulkhead Flat (loaded)	5.3	140
Bulkhead Flat (empty)	12.0	140
Coal Gondola (loaded)	4.2	105
Coal Gondola (empty)	12.0	105
Covered Hopper	7.1	125
Tank Car	5.5	95
Standard Flat Car (without trailers)	5.0	25
Standard Flat Car (with trailers)	5.0	125
Caboose	5.5	145
Conventional Passenger Coach	3.5	130
Modern Lightweight Passenger Equipment	2.0	110
Leading Freight Locomotive	24.0	160
Multi-level Auto Transporter (open)	12.3	150
Multi-level Auto Transporter (closed)	7.1	170

It will be noted that the C coefficients for empty gondolas and empty bulkhead flats are much larger than those for loaded gondolas and loaded bulkhead flats. This is due to the air swirling inside the empty car and the resulting turbulence.

Through 1988, the Association of American Railroads produced a series of reports as part of its continuing Energy program. These reports developed train resistances based upon the original Davis equation, but with a number of changes in the coefficients. Some of these changes include:

- AAR tests on Class 3 or better track indicated a negligible value for the “B” term, which was dropped.
- Modern roller bearings have a resistance of 16-18 lbs/axle, which is consistent with the 20 lbs/axle used in the modified Davis Formula. These factors change the original Davis formula to:

$$R = 1.3 + \frac{18}{W} + \frac{C_{av}^2}{WN}$$

- The speed-independent rolling resistance term (1.3) can vary from 2.13 lbs/ton (loaded car) and 1.77 lbs/ton (empty car) without wheel/rail lubrication, down to 0.8 lbs/ton to 0.7 lbs/ton with lubrication for three-piece trucks, and from 1.35 lbs/ton (loaded car) to 0.91 lbs/ton (empty car) for radial, frame braced, and primary aligned truck designs.
- Attributing the third term to aerodynamic resistance, the “C” term can be defined as follows:

$$R_{aero} = CV^2 = 0.5 \rho (CDa) V^2$$

ρ is air density, which is dependent on air pressure and temperature. The (CDa) term is the drag area of the train (drag coefficient), which is determined by summing the drag areas for all cars in the consist. The Aerodynamic Subroutine of the AAR Train Energy Model version 2.0 expresses the “C” term as a seventh order polynomial function of crosswind yaw angle for each car, and then sums over all cars. Thus the drag areas of different trains will vary considerably, depending on car design, car spacing, wind yaw angle, and train make-up. Test data used to develop this model are available in AAR Report R-685 (9).

Version 2.0 of the AAR Train Energy Model (TEM) incorporates this train resistance subroutine and data. This model permits simulation of train handling and includes fuel consumption, travel time, and speed profile as model output. To run the AAR TEM, the user does not need to gather resistance information.

2.1.4 Starting Resistance

The resistance of journal bearings is much higher at starting than when the vehicle is in motion. Depending upon the weight per axle and the temperature of the bearings, which is in turn a function of both the ambient temperature and the length of time the equipment has been stopped, starting resistance may be as high as 35 lbs per ton below 30 degrees F. An average for light and heavy cars of 25 lbs per ton at starting is a conservative assumption for above-freezing temperatures.

The starting resistance of roller bearings is essentially the same as when they are in motion. In general, a resistance value of 5 lb/ton (or less) should be satisfactory for roller-bearing equipment at above-freezing temperatures.

2.1.5 Curve Resistance and Radial Trucks

The additional train resistance due to curvature amounts to about 0.8 lbs. per ton per degree of curvature for three-piece trucks without wheel/rail lubrication. To put it another way, curve resistance can be said to be the equivalent of a grade of 0.04% per degree. For other than standard gauge track the following relationship applies (10):

$$R_c = 0.17 (\text{gauge})$$

where: R_c = Curve resistance in lb/ton per degree of curvature
gauge = gauge in feet

Primary suspension trucks (radial or self-steering, and primary aligned trucks) have less curve resistance. Experience with rail lubricators on curves has shown that their use can be expected to reduce curve resistance for three-piece trucks by as much as 45 to 50 percent. Tests have shown that they will practically eliminate curve resistance on curves of up to 9 degrees. Above 9 degrees, curve resistance is reduced by approximately 7 lb/ton. (11) Some benefit in the form of reduced curve resistance can be obtained from the use of rigid-frame or cross-braced trucks, and tighter tolerances to improve three-piece truck alignment may also reduce resistance. Hence, if curve compensation is being considered, the amount of compensation should be proportionally reduced for locations where wayside rail lubrication will be provided or improved trucks will be used.

2.1.6 Grade Resistance

The additional resistance encountered on ascending gradients is equal to 20 lbs. per ton per percent of grade, and must be added to the other train resistances (4).

2.1.7 Wind Resistance

Though on most lines trains do not move in a constant direction with respect to winds, the possible effect of winds on train resistance should not be ignored. The additional resistance due to head-winds can be accounted for by adding the average wind velocity to the train speed in computing air resistance. Wind-tunnel tests show that side winds at different yaw angles can increase train resistance significantly. The AAR Train Energy Model version 2.0 calculates the aerodynamic resistance "C" term as a seventh order polynomial function of crosswind yaw angle. Material on wind resistance will be found in AAR Report R-685 (9) and other references listed in part 2.1.16.

2.1.8 Tunnels

Tunnels can increase the train resistance considerably. Factors which affect tunnel resistance are train length, tunnel length, the ratio of the cross-sectional area of the train to the cross-sectional area of the tunnel, and tunnel roughness (12). The following table shows Canadian National C values for typical tunnel situations.

**TYPICAL VALUES OF C COEFFICIENT IN TUNNELS
FOR USE WITH CANADIAN NATIONAL TRAIN RESISTANCE FORMULA ONLY (6)**

Tunnel Length (ft)	Train Type	q = 0.40	q = 0.65
2000	Passenger	4.0	6.0
5000	Passenger	6.3	12.0
2000	Freight	8.0	12.3
5000	Freight	12.6	24.0

In the above table "q" represents the ratio of the cross-sectional area of the train to the cross-sectional area of the tunnel. The freight coefficients above are for average mixed consists. If the values provided in the table of tunnel coefficients above are lower than those given in the preceding table in section 2.1.3 for various types of passenger and freight equipment, the values for the tunnel coefficients should be adjusted upward to take into account the combined effect of high open air resistance and tunnel influence.

2.1.9 Rail Lubrication

Experience with wayside rail lubricators on curves has shown that their use can reduce curve resistance by as much as 45 to 50 percent, permitting reduced curve compensation.

Various tests have indicated large savings are available by using onboard flange lubrication. Benefits are obtained on tangent as well as curved track and are additional to benefits derived from wayside rail lubrication. Reductions averaging 0.8 lb/ton have been obtained for loaded cars on curves using this technique (13).

A study by MIT found that track lubrication cut energy losses by roughly 25% over most of the operating speed range. The use of radial trucks gave results comparable to track lubrication, except that stability was increased (and losses decreased) at higher speeds on good track. Suspension losses increased for conventional trucks in lubricated curves over that found in dry curves, even though the total resistance was greatly reduced. On class 5 curves, the improvement due to lubrication for curves from 2 to 5 degrees averaged 35% for the AAR wheel (14).

2.1.10 Track Quality, Track Modulus, and Concrete Ties

Higher track quality can reduce train resistance by reducing suspension losses and power losses in the wheel/rail contact area. MIT studies concluded that the level of track roughness has a considerable impact on dynamic resistance at low and moderate speeds on tangent track. On good track at high speeds, the losses are dominated by hunting, and roughness is less important. Curving resistance is less affected by track roughness, for the leading outer wheels are in flange contact beyond 2 or 3 degrees of curvature; on tangent track, roughness increases resistance by bringing the flanges into contact (14). Tests have shown that an increase in track quality from FRA class 4 to class 6 reduced rolling resistance by 0.3 lb/ton at 20 mph to 0.5 lb/ton at 60 mph on tangent track for cars with a gross weight of 104 tons. This increase in track quality reduced rolling resistance on curves of up to 2 degrees by 0.4 lb/ton for the same cars. Beyond 2 degrees little improvement was observed (15).

Track quality can be improved by using concrete ties instead of wooden ties, using continuous welded rail instead of jointed rail, increasing the depth of the ballast section, increasing rail cross-section, and in other ways strengthening the track structure.

Studies have shown that train resistance can be substantially reduced when trains are operated over track with concrete ties rather than wooden ties. The reduction is due to the higher track modulus which implies stiffer track. There results a decrease in energy lost in the car suspension and in the roadbed. The installation of concrete ties in place of wooden ties under 132 lb rail, for example, can decrease rolling resistance by approximately 0.5 lb/ton for cars with a gross weight of 130 tons. For empty cars (25 tons), the reduction under the same circumstances is approximately 0.1 lb/ton (16).

2.1.11 Articulated Cars

Articulated cars can be used to reduce train resistance, due to fewer axles. Examples are found in high speed passenger trains and multiple-unit intermodal cars.

For example, to calculate train resistance for a high speed passenger train consisting of "n" vehicles, where the C coefficient for leading vehicles is Cld and the C coefficient for trailing vehicles is Ctr, the overall C coefficient for such a combination will be:

$$C \text{ combined} = \frac{Cld + (n-1) Ctr}{n}$$

Note that lower-case n above refers to the number of vehicles. As usual, upper-case N in the train resistance formula would represent the number of axles in the combination.

2.1.11 Four-Wheel Cars

Four-wheel (two axle) cars can contribute to reduced train resistance due to fewer axles and reduced weight. The use of two-axle cars allows N to be set at 2, rather than 4 as is normally the case, in the train resistance formula. Curve resistance can be increased due to a longer rigid wheelbase, however.

2.1.13 Empty Gondola, Hopper and Bulkhead Flat Cars

As noted in the table in part 2.1.3 above which gives C coefficients for various car types, empty gondolas have a much higher C coefficient than loaded gondolas. This is due to the open space within the empty cars which can trap a good deal of air and cause substantial turbulence. This increase can be of the order of 150% to 200%. (17) The same effect applies in the case of empty open top hopper cars but to a reduced degree.

2.1.14 High Speed Passenger Trains

Streamlining can be used to lower the C coefficient in the train resistance formula. With a high degree of streamlining, the C coefficient for leading vehicles can be reduced by as much as 60% and that for trailing vehicles can be reduced by 33% compared with the coefficients for conventional passenger trains of the style built during the 1950's. (8)

2.1.15 Other Factors

Air conditioning, atmospheric temperature, equipment weight, locomotive contour, passenger train contour, rail support, rail weight and condition, speed on curves, track conditions, and forces due to side winds are other factors which can affect train resistance.

2.1.16 References

1. W. J. Davis, Jr. "Track Resistance of Electric Locomotives and Cars," *General Electric Review*, October 1926.
2. J. K. Tuthill. "High Speed Freight Train Resistance," University of Illinois *Engineering Bulletin* 376, 1948.
3. A. I. Totten. "Resistance of Light Weight Passenger Trains," *Railway Age*, Vol. 103, July 17, 1937.
4. W. W. Hay. *Railroad Engineering*, 2nd Ed., John Wiley & Sons, New York, 1982.
5. *Railway Locomotives & Cars*, Simmons-Boardman Publishing Corp., October 1966, pages 23 and 54.
6. *Canadian National Railways Transportation Design Standards*, October 1990.
7. *Canadian National Railways Transportation Design Standards*, June 1974.
8. *Canadian National Railways Transportation Design Standards*, October 1986.

9. M. A. Gielow and C. F. Furlong. *Results of Wind Tunnel and Full-Scale Tests Conducted From 1983 to 1987 in Support of the Association of American Railroads Train Energy Program*, Association of American Railroads, December 1988.
10. *Canadian National Railways Train Performance Calculator Manual*, January 1987.
11. R. A. Allen, J. A. Elkins, J. T. Dincher and J. F. Laery, AAR, S. G. Guins, Kaser Associates, "Effect of Truck Performance on Train Resistance," Presented at the Railroad Energy Technology Conference II at Atlanta, Georgia, May 1986.
12. Paolo Pellis, "Resistances of the Air in the Running of Train in Tunnel," *Rail International*, April 1980.
13. A. John Peters and Kenneth C. Rownd, "Wheel-Rail Lubrication Research," Transportation Test Center, Presented at the Railroad Energy Technology Conference II at Atlanta, Georgia, May 1986.
14. J. R. Bailey and J. K. Hedrick, "Rail Vehicle Energy Dissipation due to Lateral Vehicle/Track Interactions," Massachusetts Institute of Technology, Cambridge, Presented at the 10th LAVSD Symposium on Dynamics of Vehicles on Roads and Tracks, Prague, Czechoslovakia, August 1987.
15. J. R. Bailey, X. L. Shen, S. P. Singh and J. K. Hedrick. Vehicle Dynamics Laboratory, Department of Mechanical Engineering, M.I.T., Cambridge, Mass. AAR, Chicago Technical Center, "The Influence of Track Quality on Train Resistance," Presented at the Third International Heavy Haul Railway Conference, Vancouver, BC, October 13-17, 1986.
16. G. W. English, R. W. Lake, M. D. Rooney and J. Taggart, *Canadian Railway Energy Conservation and Alternate Fuels*, Canadian Institute of Guided Ground Transport, Queen's University, Kingston, Ontario, Report No. 78-13, August 1978.
17. R. Engdahl, Consultant, R. L. Gielow and J. C. Paul, Airflow Sciences Corporation, "Train Resistance—Aerodynamics," Volume II of II Open Top Car Applications, Canadian National Railways correspondence, June 1974.

AMERICAN RAILWAY ENGINEERING ASSOCIATION

Part 5

Economics and Location of Defect Detector Systems

5.1 INTRODUCTION

Defect detector systems are used by railroads to alert operating and maintenance personnel to defects in rolling stock, lading, motive power and wayside conditions that if undetected could cause derailments or hazardous conditions, possibly catastrophic in nature. Prevention of such occurrences not only reduces operating costs for railroads but also saves lives and provides a more damage free, on-time service to customers.

It should be noted that the detector itself is but one device that acts with other devices or equipment to alert and warn railroad personnel of a dangerous situation. These other devices and equipment may include wheel detectors (counters), electronic or microprocessor equipment to analyze and store data, interfaces to wayside signal systems and communications facilities.

Defect detector systems may be in two categories:

1. Systems to detect defects or undesirable conditions in rolling stock and motive power. They are:
 - Dragging equipment
 - Flat wheel/impact
 - High, wide load (clearance)
 - Hot bearing
 - Acoustic bearing
 - Hot wheel
 - Loose wheel/broken flange
 - Wheel crack
2. Systems to detect undesirable conditions along the right-of-way that will endanger the safe operation of trains. They are:
 - Bridge movement
 - Earth movement (earthquake or subgrade or ballast shifting)
 - Falling earth (rocks, trees) upon the track
 - Fire (wood trestles, snow sheds)
 - High water
 - High wind
 - Snow slides or avalanches

Category 1 defect detectors are usually the stand alone type. However, some railroads may place two or more at a location so that the detectors share the wheel counters, alarm and data transmission facilities required to pinpoint and announce results of detector actuation.

Clusters typically include:

- Hot bearing and dragging equipment detectors
- Hot bearing and hot wheel detectors
- Hot bearing, hot wheel and dragging equipment detectors

Also Category 1 defect detectors usually store results at the wayside with an immediate answer—no defects found, or specific defects found—transmitted via voice radio to the crew of the passing train. Results may be sent simultaneously to dispatching or operating headquarters. If no defects are found, transmission to the dispatcher may be delayed.

Category 2 detectors are usually interconnected to the wayside signal system in such a way as to give an approaching train a Stop signal before it reaches the hazardous condition. If time permits, the Stop signal is preceded by an Approach signal.

The objective of any detection system is to promptly alert train crews of the hazards of rolling stock or of wayside conditions that could cause unsafe operation of a derailment.

5.2 TYPES OF DEFECT DETECTOR SYSTEMS

Rolling stock (Category 1) detectors include:

- Dragging equipment: It detects the presence of broken, misplaced or hanging mechanical parts that have dropped below a predetermined clearance line above and between rails or adjacent to and outside of the rails.
- Flat wheel/impact: It detects flat spots on wheels that are larger than a predetermined size or out of round wheels.
- High, wide load: It detects cars, engines, loads or damaged items that infringe on a specific clearance outline, such as Plate C.
- Hot bearing: It measures heat originating from roller bearing and plain bearing journals and detects defects that radiate heat greater than a predetermined temperature above ambient temperature.
- Acoustic bearing: It records and analyzes the sound originating from bearings on a passing train and can report which sounds are a result of bearing defects.
- Hot wheel: It measures heat on wheels originating from brake shoes rubbing on wheel treads and detects wheel temperatures that are greater than a predetermined temperature.
- Loose wheel/broken flange: It detects wheels that have become loose and have shifted along their axles by a predetermined distance. Also, it detects wheels that have pieces broken from the flange greater than a predetermined size.
- Wheel crack: It detects defects (transverse surface thermal cracks or other geometric irregularities) on wheel treads and flanges that are greater than a predetermined size.

Wayside condition (Category 2) detectors include:

- Bridge movement: It detects the movement of bridge girders, piers, abutments or other structural members that could move the tracks out of proper alignment or provide insufficient support for a train crossing the bridge.
- Earth movement (earthquake): It detects movement of the earth or subgrade under the track that could make it unsafe for a train to move over the disturbed ground.
- Falling earth (rock slide): It detects the presence of earth, rocks, trees or other obstacles on the right-of-way or track that would interfere with the safe movement of trains.
- Fire: It detects fires on wood trestles, snow sheds or other flammable structures that would, if partially or totally destroyed, be hazardous to train operations.
- High water: It detects the rise of water that could impair the loading capability of the track structure or of a bridge. Also, high water could create inadequate clearance for boats on navigable streams to pass under railroad bridges.
- High wind: It measures wind velocity and direction, and will alert train crews or dispatchers when the wind is greater than a predetermined amount.
- Snow or ice slide (avalanche): It detects snow or ice falling or moving onto the tracks or other structures such as to make it unsafe to operate trains.

5.3 LOCATION OF DEFECT DETECTORS

Category 1 defect detectors to monitor rolling equipment should be located with consideration for where the failure is most likely to occur, the probable consequences and the most effective method of correction.

Failures such as loose wheels, flat wheels, broken flanges or plates, shifted loads or dragging equipment may occur randomly and it is impossible to accurately place a detector to intercept a catastrophic failure. Further, they are difficult to correct on line of road.

For this reason, dragging equipment, flat wheel/impact, loose wheel/broken flange and wheel crack detectors are most effective on the inbound leads to terminals with car repair facilities or on the hump approach in classification yards.

The flat wheel/impact detector may be located on line of road on tangent, level track where no braking occurs so a train operating at normal speed can be monitored.

Dragging equipment detectors are also located on line of road in approach to junctions, yards, bridges, tunnels or other important locations where a derailment would cause an especially disastrous traffic blockage.

These detectors must be located at least braking distance from the protected location so that when the train crew is alerted resulting from detector operation, the train can be stopped before reaching that location. Braking distance is determined using the heaviest train operating at maximum speed in the territory.

High, wide load (clearance) detectors are similarly located in approach to bridges on the rail line or crossing over the rail line, tunnels or yards. On line-of-road these clearance detectors should be located at least braking distance from the bridge, tunnel or yard, so detector operation can alert the train crew enabling it to stop the train before reaching the bridge, tunnel or yard.

Since many lading shifts occur during yard switching, a clearance detector to check outbound trains may be desirable.

Hot bearing, acoustic bearing and hot wheel detectors are located along line-of-road and some are located in approach to yards. These detectors should be located on tangent, level track where trains are not braking. Also, they should be far enough from curves so freight car trucks are not hunting or skewed.

Hot bearing detectors are generally spaced 20-25 miles apart, but experience with roller bearings indicates a spacing of 15 miles between detectors would be better.

If possible, hot bearing and hot wheel detectors should be located such that if an overheated bearing or wheel is detected, and the train crew alerted, the train in stopping with a normal service brake application will be close to a siding where the car with the overheated bearing can be set off.

Acoustic bearing detectors that detect incipient failures in journals should be located in areas of low ambient noise, again on tangent, level track where trains are not braking, far enough away from curves so trucks are not hunting or skewed.

At present, acoustic detectors are used to supplement hot bearing detectors because they detect incipient failures in bearings.

Hot wheel detectors are often located at the same site as hot bearing detectors and the same location criteria applies.

Category 2 wayside condition detectors are located where a failure or hazard will occur that will make train operation unsafe. They include:

Bridge movement detectors are located where bridge members may be struck by passing vehicles such as trucks, buses, boats or barges or where piers or abutments may settle.

Earth movement (earthquake) detectors or detectors buried in the subgrade are located where such earth movement is possible or where it has occurred in the past.

Falling earth (falling object) detectors are often located in cuts, along mountain sides or where earth, rocks, mud or trees, loosened by rain, snow or winds, cause them to fall on to the right-of-way or track creating a hazardous condition. Such detectors may consist of fencing so that small object may be held off the track. If possible, rock slide fences are located several feet from the ends of ties.

Fire protection detectors usually consisting of wire with fusible or soldered links that are mounted on wood trestles, wood bridge decks, snow sheds or other structures subject to fire damage. These wires may be attached to vertical support timbers of main piers or to other structural supports. They may be installed on the roofs and sides of snow sheds.

High water detectors are located in river or creek beds upstream from the location of the railroad river crossings. High water detectors can be located several miles upstream to give warning of an impending flash flood. At river or bay crossings near oceans where tides prevail, such high water detectors may be located at or near the railroad bridge if it would be endangered by a high tide lifting boats into the clearance pattern under the bridge. Also of concern might be high water weakening earth around bridge piers and abutments.

High wind detectors should be located where severe wind storms are likely to create hazards to train operation or damage to structures. In severe cases, such winds can blow trailers and containers off flat cars or even move standing cars or derail cars in moving trains.

Snow slide or avalanche detectors are located where heavy snow is likely to occur. In mountain territory, the detectors may be several miles away to give some warning time before the snow or avalanche arrives at the railroad right-of-way.

Also, snow detectors are installed at power switch locations, especially in traffic control territory, to alert dispatchers when snow is falling so they can turn on switch heaters (snow melters or snow blowers) to keep switches free of snow and ice.

5.4 ALERT TRAIN CREWS/DISPATCHERS

Because Category 1 detectors inspect moving trains, it is important that upon detector actuation, train crews are promptly alerted as to results, so if required the train can be stopped. Simultaneously, the dispatcher should be alerted if an alarm condition exists.

Detectors located on approaches to yards or yard lead tracks, where trains normally stop, the yardmaster, dispatcher and mechanical foreman are notified of the results of detector actuation. Train crews may or may not be alerted. If the detectors are on the lead to the hump in a retarder classification yard, the hump locomotive engineer will be alerted if a detector alarms.

High, wide load (clearance) detectors located on an outbound yard lead should transmit an alarm to the yardmaster, dispatcher and to the train crew so they can stop the train. Mechanical forces can then be alerted and can correct the problem.

Hot bearing and hot wheel detectors located along line-of-road are usually equipped with base radio stations. A voice radio message is broadcast to the train crew informing them that no defects are found or the specific defects found and where located.

In some instances, the defect detector data are simultaneously transmitted to the dispatcher. In others, data is sent to a computer or readout device in the dispatcher's office. If no defects are found, data transmission may be delayed until several trains' data can be sent or the dispatcher requests the data.

The rolling stock detectors may make use of special wayside indicators or may be interconnected with the wayside signal system.

With a cluster or group of rolling stock defect detectors such as hot bearing, hot wheel and dragging equipment, the associated equipment will provide such information as time, date, direction of travel, train speed, length of train, time train arrived at detector site and time last car cleared the detectors. This information plus defect detector generated data can be temporarily stored and then sent to a computer at a central point or dispatcher's office for further analysis and handling.

Computer analysis of hot bearing or hot wheel detector data from several detectors may be desirable to alert train crews of bearings that are heating up. With that information, cars may be set out before the journals reach the critical or alarm condition.

Acoustic bearing detectors, recently developed, and being more widely used to supplement hot bearing detector, track incipient bearing failures. Hence, acoustic bearing detection results are often stored at the site and transmitted to a dispatcher or mechanical office for analysis.

Category 2 (wayside condition) detectors are placed to prevent potential accidents. It is essential to warn approaching trains in time for them to be stopped before reaching the hazard location. The detectors can be interconnected to the wayside signal system to alert the train crew, or an automated warning message can be transmitted by voice radio.

If fixed signals are employed, they should be located to give advance warning through an Approach signal with the final Stop signal at a point before the hazard condition. This ensures that an occurrence after the train has passed the Approach signal will still provide a warning via the Stop signal.

If wayside signals are not in service some form of wire line, fibre optic cable, radio or microwave data transmission should be provided to alert the dispatcher who can alert the train crew via voice radio. In some instances, it may be cost effective to have a base radio station at the detector location which can transmit a voice warning message via radio to train crews.

In some instances where high water or avalanche detectors are in service off the right of way, prompt reporting of detector actuation to the dispatcher may provide time for personnel to inspect the rail line protected by these detectors.

For dragging equipment and high, wide load detectors, the important point is to alert the train crew promptly so the train can be stopped before it reaches the protected object or track area. Here again, a voice radio message from the detector to the train provides prompt alerting. Special wayside indicators or interconnection with the signal system may be used.

5.5 ECONOMICS OF DETECTORS

Any detection system must be evaluated on the basis of the results obtained for the costs involved. As with many management decisions, the advantages are often subjective and difficult to evaluate on a cash basis. Certain systems, such as hot bearing detectors and slide detectors, are relatively easy to evaluate. Others, such as hot wheel or high water indicators, may be more difficult unless they can be consolidated with other reliable indicators that will improve labor efficiency. If routine bad weather inspections are a management policy, a high water gauge may have little practical value.

Some of the intangibles to consider are customer satisfaction, decreased yard congestion, reduced labor costs and lower equipment costs (both capital and car-hire) when reliable schedules can be maintained.

Generally speaking, some basic defect detector costs can be determined from the following:

Initial detector equipment cost:

1. Purchase cost or price of detector.
2. Cost of housing.
3. Cost of power and/or connections.

4. Cost of communications systems.
5. Cost of associated equipment and peripheral devices.
6. Cost of installation of items 1 through 5.

Annual expenses:

Service and maintenance cost of the following:

7. Detector
8. Communications system
9. Peripheral devices and associated equipment
10. Power supplies

Other factors to be considered:

11. Expected life of detector
12. Expected life of communications systems
13. Expected life of associated equipment and peripheral devices

If more than one type of detector is employed at a location, the percentage of the peripheral devices and associated equipment that support each type of detector must be determined and factored into the costs.

For proper evaluation and direct comparison with other capital budget considerations, calculations should be on a discounted cash flow basis.

Determine costs that are eliminated by use of detectors, such as numbers of derailments prevented because defect detectors alerted train crews in time to safely stop trains before reaching hazardous conditions.

Costs eliminated include:

- Damage to rolling stock
- Damage to track
- Damage to motive power
- Injury or death to people (employees or others)
- Costs to evacuate people in case of hazardous material spills.
- Cost of clean up of wastes and derailed equipment
- Damage to lading
- Insurance and overhead costs
- Cost to reroute trains
- Payments to fire, police and public emergency response agencies.
- Costs or payments to people other than railroads for inconvenience or injury because of a wreck.

If more than one detector is involved, determine percent of prevention due to each type of detector.

Determine cost of false stops due to failure of detector or failure of train crew to find the defect or hazardous condition.

Determine number of false stops on an annual basis.

From total costs of derailments must be subtracted costs of false stops.

It may be possible to develop an exposure factor for each type of detector and location by knowing the number of detectors, number of cars handled and number of actual derailments and those prevented. A comparison of sites can be analyzed to help determine any other factors which may lead to problems picked up or not detected, at specific locations.

Proposed 1992 Manual Revisions To Chapter 27—Maintenance of Way Work Equipment

An informational report on “Bar Codes and Their Application for Roadway Work Equipment” was published in the 1991 A.R.E.A. October Bulletin No. 732. It is proposed to add this report as Manual material to Part 1—General of Chapter 27.

Proposed 1992 Portfolio Revisions

Proposed changes to the Portfolio involve Plan 100, Section M2. Manganese Steel Castings and Section M7. Rolled Mild Steel. In Section M2, paragraph M2.5 Workmanship, recommendations on radiographic testing of castings are proposed, which refer to new plans 1012 to 1017 containing evaluation criteria and locations for various castings. In Section M7, Paragraph M7.2.1 it is proposed to add ASTM A36 Steel as an alternate to ASTM A663 steel, since A663 has become increasingly difficult to obtain.

The specific changes to Section M.2 and M.7 are as follows:

SECTION M.7 ROLLED MILD STEEL

Reword paragraph M.7.2.1 to:

“Bar and bar size shape stock shall be produced in conformance with the latest issue of ASTM A663 or A36 Specification for Merchant Quality Hot-Rolled Carbon Steel Bars, Grade 60.”

SECTION M.2 MANGANESE STEEL CASTINGS

Replace Section M2.5 Workmanship with the following text, and add Plans 1012 to 1017 to the Portfolio.

2.5 WORKMANSHIP

M2.5.1 The castings shall be true to the pattern and conform to the shapes and sizes indicated by the purchaser's drawings in accordance with good foundry practice.

M2.5.2 Large protrusions, sharp fins, sand holes and chills on the outside of the casting shall be removed.

M2.5.3 Castings shall be free from hot tears, cracks and other injurious defects. Castings shall be free from cold shuts which will impair serviceability.

M2.5.4 When specified, radiographic testing and/or sectioning will be used to qualify castings for acceptance of internal soundness, by the manufacturer. To verify radiographic testing, the qualification process may include sectioning of castings.

M2.5.4.1 Internal soundness of castings shall comply to radiographic testing quality standard levels, as specified in Plan 1012, 1013, 1014, 1015, 1016 and 1017 (proposed plan numbers).

M2.5.4.2 Radiographic testing shall be done in conformance with the latest issue of the following ASTM Specifications:

- E-94. Recommended Practice for Radiographic Testing
- E-142. Controlling Quality for Radiographic Testing
- E-446. Reference Radiographs up to 2 inches in thickness, (0"-2")
- E-186. Reference Radiographs for Heavy Wall Steel Casting, (2"-4-1/2")
- E-280. Reference Radiographs for Heavy Wall Steel Casting, (4-1/2"-12")

M2.5.4.3 The continued frequency of radiographic testing and surface area coverage of components for castings meeting soundness qualification standards will be specified by the purchaser.

M2.5.5 Where testing, in accordance with M2.5.4 thru M2.5.4.3 is not specified, castings shall be free from sand holes, gas pockets, and other imperfections, unless; these imperfections are in locations where they will not appreciably weaken the casting or impair its wearing qualities.

M2.5.6 Where testing, in accordance with M2.5.4 thru M2.5.4.3 is not specified, castings shall be free from all shrinkage cracks unless they are of the size and in such location that they will not adversely affect the service life of the casting. Shrinkage cracks will not be permitted at any part of the tread surface.

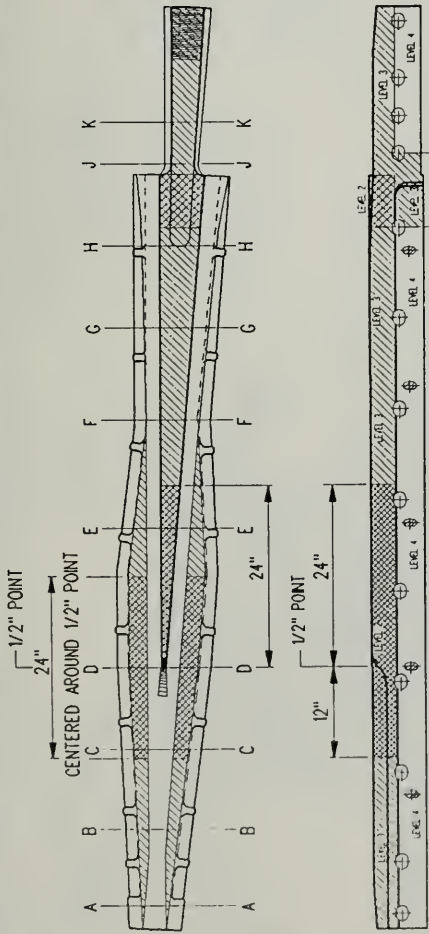
M2.5.7 As cast tread surfaces within 2-1/2" of the gage line and flangeway walls 1" down from the tread shall be free of imperfections unless they are so small that they will be practically removed by the finish grinding.

M2.5.8 Castings shall be free from twist and reasonably true, both as to general surface and alignment, and shall not show signs of straining or undue denting from the straightening operation.

M2.5.9 The bottom part of the casting which rests on plates or ties shall be reasonably straight and without twist, and shall be free of surface irregularities or imperfections that would prevent a good bearing.

M2.5.10 Castings shall be without sharp corners at the base, having minimum radii of 1/4" at the intersection of the inside vertical wall and the bottom, and 1/8" at the intersection of the outside vertical wall and the bottom.

M2.5.11 Bolt holes in castings shall not be enlarged by cutting or reaming with an oxyacetylene torch, unless specifically approved by the purchaser.



SECTION OF CASTING ALONG CENTER OF FROG



SECTION J-J



SECTION K-K

NOTES

WITH REFERENCE TO ASTM E 446, E 186, E 280, AND THE ASTM REFERENCE RADIOGRAPHS, ALL A.R.E.A. TYPE MANGANESE FROG CASTINGS MUST MEET THE FOLLOWING CRITERIA:

- MUST BE LEVEL 2.
- MUST BE LEVEL 3.
- MUST BE LEVEL 4.

ASTM LEVELS APPLY TO THE FOLLOWING DEFECTS OR DISCONTINUITIES:

- ASTM CATEGORY 'A' - GAS POROSITY
- ASTM CATEGORY 'B' - SAND AND SLAG INCLUSIONS
- ASTM CATEGORY 'C' - SHRINKAGE

THIS SPECIFICATION APPLIES TO ALL RRM FROGS A.R.E.A. PLAN 616, 621 AND ALSO TO A.R.E.A. CROSSINGS PLAN 750, 751, 768 AND 769.

AREA PLANS 616 AND 621 SHOWN.

MANGANESE CASTINGS
INTERNAL SOUNDNESS SEVERITY LEVELS

PLAN NO. 1012-92



SECTION G-G



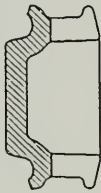
SECTION E-E



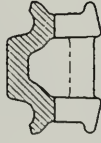
SECTION C-C



SECTION A-A



SECTION H-H



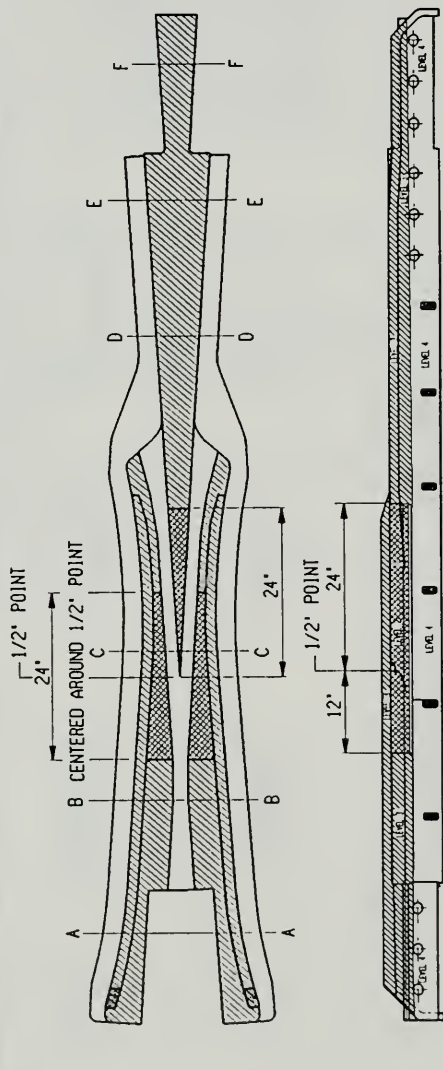
SECTION F-F



SECTION D-D



SECTION B-B



SECTION OF CASTING ALONG CENTER OF FROG

NOTES

WITH REFERENCE TO ASTM E 446, E 486, E 280, AND THE ASTM REFERENCE RADIOGRAPHS, ALL A.R.E.A. TYPE MANGANESE FROG CASTINGS MUST MEET THE FOLLOWING CRITERIA:

■ MUST BE LEVEL 2.

■ MUST BE LEVEL 3.

■ MUST BE LEVEL 4.

ASTM LEVELS APPLY TO THE FOLLOWING DEFECTS OR DISCONTINUITIES:

-ASTM CATEGORY 'A'-GAS POROSITY

-ASTM CATEGORY 'B'-SAND AND SLAG INCLUSIONS

-ASTM CATEGORY 'C'-SPRINKLE

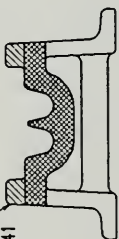
THIS SPECIFICATION APPLIES TO A.R.E.A. FROGS PLAN 641, 671 AND ALSO TO A.R.E.A. CROSSINGS PLAN 774 AND 775.

A.R.E.A. PLAN 641 SHOWN.

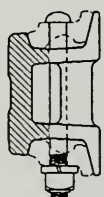
AS REQUIRED
GUARD AS PER
DRAWING 641



SECTION A-A



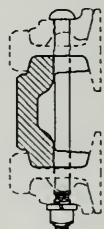
SECTION C-C



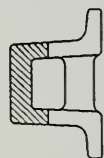
SECTION E-E



SECTION B-B



SECTION F-F

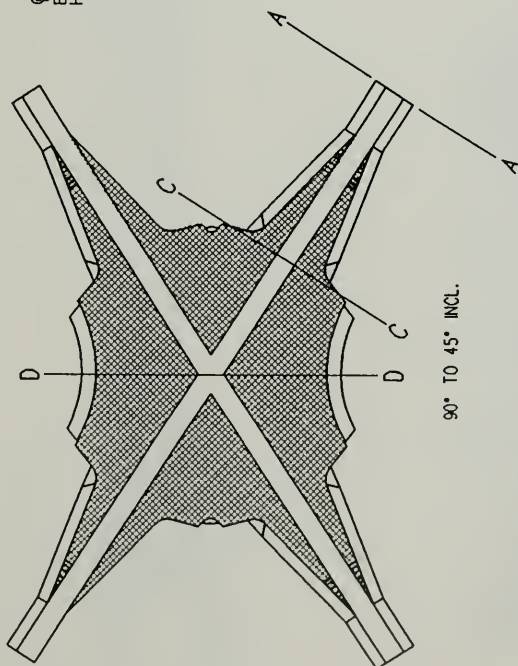
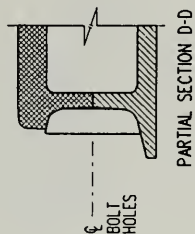
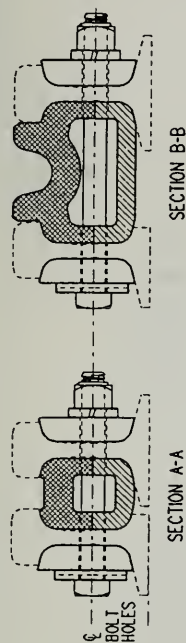


SECTION D-D

American Railway Engineering Association

MANGANESE CASTINGS
INTERNAL SOUNDNESS SEVERITY LEVELS

PLAN NO. 1013-92



NOTES

WITH REFERENCE TO ASTM E 448, E 186, E 280, AND THE ASTM REFERENCE RISK MAPS, ALL CASTINGS SHALL MEET THE FOLLOWING CRITERIA:

⊗ MUST BE LEVEL 2.

⊗ MUST BE LEVEL 3.

⊗ MUST BE LEVEL 4.

ASTM LEVELS APPLY TO THE FOLLOWING DEFECTS OR DISCONTINUITIES:

-ASTM CATEGORY 'A' - GAS POROSITY

-ASTM CATEGORY 'B' - SAND AND SLAG INCLUSIONS

-ASTM CATEGORY 'C' - SPRING

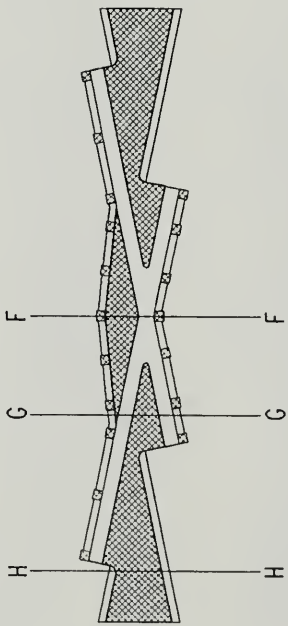
THIS SPECIFICATION APPLIES TO ALL MANGANESE DIAMOND INSERTS A.R.E.A. PLAN 746, 747, 748 AND 749.

American Railway Engineering Association

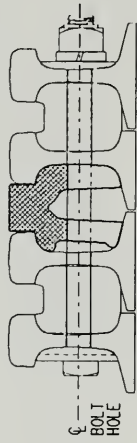
MANGANESE CASTINGS

INTERNAL SOUNDNESS SEVERITY LEVELS

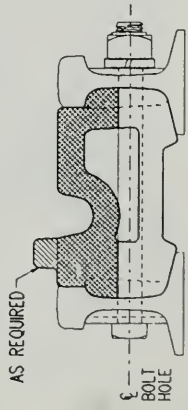
PLAN NO. 1014-92



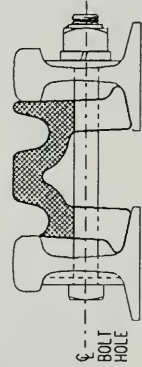
CENTER FROG



SECTION H-H



SECTION F-F



SECTION G-G

NOTES

WITH REFERENCE TO ASTM F 446, E 185, E 280, AND THE ASTM REFERENCE RADIographs, ALL AREA TYPE MANGANESE FROG CASTINGS MUST MEET THE FOLLOWING CRITERIA:

▨ MUST BE LEVEL 2.

▨ MUST BE LEVEL 3.

▨ MUST BE LEVEL 4.

ASTM LEVELS APPLY TO THE FOLLOWING DEFECTS OR DISCONTINUITIES:

-ASTM CATEGORY 'A' - CRACKS

-ASTM CATEGORY 'B' - SAND AND SLAG INCLUSIONS

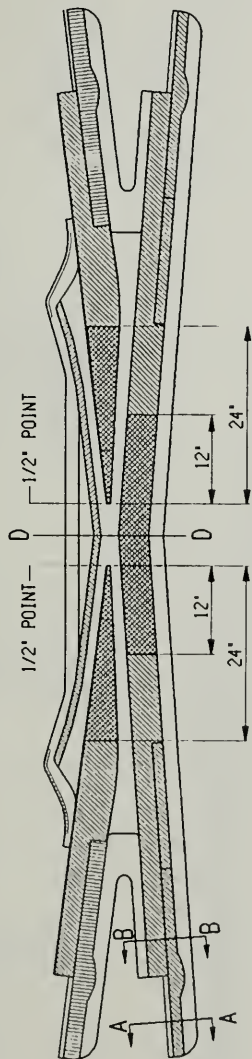
-ASTM CATEGORY 'C' - SHRINKAGE

THIS SPECIFICATION APPLIES TO ALL MANGANESE CENTER FROG INSERTS AREA, PLAN 788 AND 789.

American Railway Engineering Association

MANGANESE CASTINGS
INTERNAL SOUNDNESS SEVERITY LEVELS

PLAN NO. 1015-92



CENTER FROG

NOTES

WITH REFERENCE TO ASTM E 446, E 486, E 280, AND THE ASTM REFERENCE RACKGRAPHS, ALL APPLICABLE TYPE MANGANESE FROG CASTINGS MUST MEET THE FOLLOWING CRITERIA:

- [Cross-hatched pattern] MUST BE LEVEL 2.
- [Diagonal lines pattern] MUST BE LEVEL 3.
- [Horizontal lines pattern] MUST BE LEVEL 4.

ASTM LEVELS APPLY TO THE FOLLOWING DEFECTS OR DISCONTINUITIES:

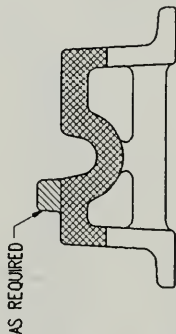
- ASTM CATEGORY A - GAS POROSITY
- ASTM CATEGORY B - SAND AND SLAG INCLUSIONS
- ASTM CATEGORY C - SPRING

THIS SPECIFICATION APPLIES TO ALL SOLID MANGANESE CENTER FROG INSERTS AREA, PLAN 774 AND 775.

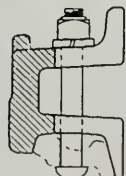
American Railway Engineering Association

MANGANESE CASTINGS
INTERNAL SOUNDNESS SEVERITY LEVELS

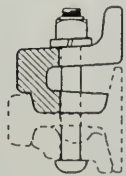
PLAN NO. 1016-92



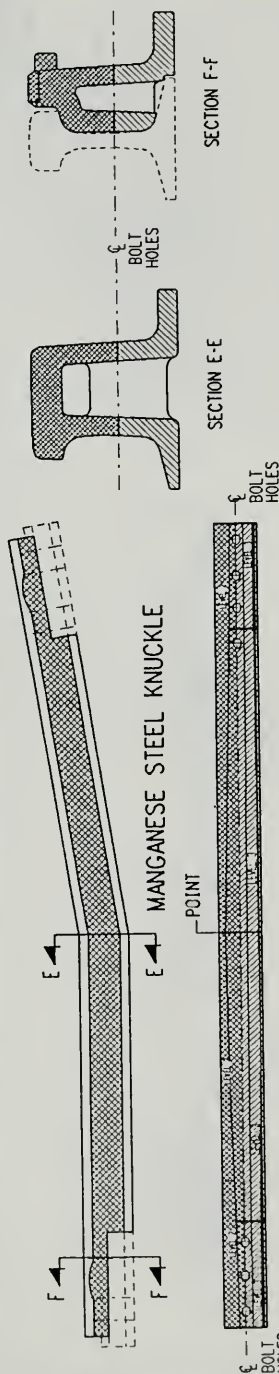
SECTION D-D



SECTION B-B



SECTION A-A



NOTES

WITH REFERENCE TO ASTM E 446, E 586, E 280, AND THE ASTM REFERENCE RADIOGRAPHS, ALL A.R.E.A. TYPE MANGANESE FROG CASTINGS MUST MEET THE FOLLOWING CRITERIA:

██████ MUST BE LEVEL 2.

▨ MUST BE LEVEL 3.

▤ MUST BE LEVEL 4.

ASTM LEVELS APPLY TO THE FOLLOWING DEFECTS OR DISCONTINUITIES:

-ASTM CATEGORY "A" - GAS POROSITY

-ASTM CATEGORY "B" - SAND AND SLAG INCLUSIONS

-ASTM CATEGORY "C" - SHRINKAGE

THIS SPECIFICATION APPLIES TO ALL MANGANESE KNUCKLES A.R.E.A. PLAN 821

American Railway Engineering Association

MANGANESE CASTINGS

INTERNAL SOUNDNESS SEVERITY LEVELS

PLAN NO. 1017-92





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ENGINEERING ASSOCIATION

BULLETIN
No. 736

VOL. 93 (1992)

MAY 1992

ROOM 7702
50 F St., N.W.
WASHINGTON, D.C. 20001
U.S.A.

**A RAILWAY
FROM
NORTH AMERICA
TO
ASIA**



Details of Proposed Railway—see page 155

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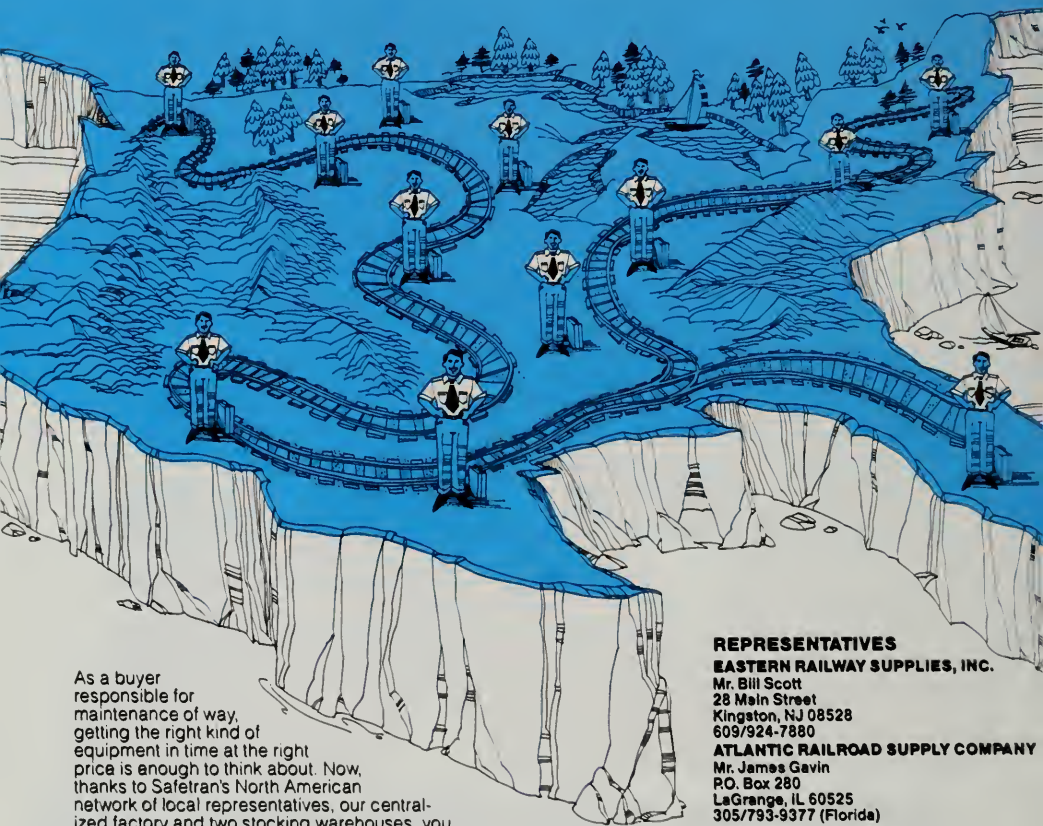


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AN INTERHEMISPHERE RAILROAD BETWEEN NORTH AMERICA AND ASIA VIA A TUNNEL UNDER THE BERING STRAIT

By: G. Koumal*

Introduction

I have come here today to discuss what hopefully will become one of the great transportation projects of the 21st century. A railroad which would connect the North American and Asian continents, in fact the western and eastern hemispheres, via a tunnel under the Bering Strait between Alaska and Siberia is being planned. Most of you present here must wonder why a mining engineer is at this conference talking about a railway project. Actually there is much in common between railroads and mining.

Quite a plausible case can be made that railroading, as we know it today, originated in the mines. Flanged wheels and wooden rails were used in the mines around Newcastle, England in the early 1600's. It was again an English mining man, Mr. Richard Trevithick of Cornwall, who gave us the first locomotive, which hauled a train over track for the first time in February, 1804. But the main reason for a mining engineer to be addressing this conference is that the centerpiece of this railway project is a 50 mile tunnel between North America and Asia across the Bering Strait between Alaska and Siberia. We should stop here for a short geography lesson.

When looking at a typical map of ocean shipping routes a person might say, "Why go all the way up north and then come back south on a railroad when you can go straight across the Pacific by ship to get

from North America to Asia." This view comes from the usual portrayal of the world on a flat map but the real story comes clear when we look at a polar map as you would look at the top of a world globe as shown here on the left. A straight line from Chicago to Beijing, China, falls north, not south of the Bering Strait. When we started working on the project to connect North America with Asia by constructing a main line railroad via a tunnel under the Bering Strait, our main justification was the access to mineral resources in Siberia that the railroad would facilitate and the industrial development the transport artery would promote. However, we soon realized that the existing Pacific Rim transportation markets, which the Intercontinental Railroad would serve, may be an even more important factor for the project's justification.



Polar map showing straight line from Chicago to Beijing.

*President, Engineering Technology International

Initially, we did not realize that an identical concept was suggested in 1905/06 and some definite steps were taken toward the project's realization: Under the leadership of Loicq de Lobel, the Trans-Alaska-Siberia Railway Company was incorporated in New Jersey and had a capital of \$6,000,000.00. The cost of the project was estimated to be between \$200,000,000 and \$300,000,000. Technically the project was considered to be a cinch. We are not so brazen as to consider an undertaking of this magnitude to be a cinch, but we believe that with today's technology and know-how the project can be realized much easier than at the beginning of our century. Although it will be a little more expensive to build now.

The Railroad:

We believe that the railroad is the most economically effective and environmentally friendly mode of long distance, overland transport known to man, for large quantities of freight. We also believe that with development of new technology the railroad will maintain this position way into the future. The high point of the Age of Railroads is yet to come. It is only logical that we have selected the railroad as part of our project. In public response to the project concept, most people are fascinated by the tunnel under the Bering Strait. However, it is the intercontinental railroad which is the most important element of the engineering concept. Rail is the only mode of overland all weather, year-round transport with a proven operational record in the far northern latitudes. Long distances and some mountain crossings are involved, as well as the need to cope with construction in a harsh climate. However, similar railroad construction conditions have been encountered before, at a number of sites.

In one phase of the construction it is proposed to connect existing rail terminals in Canada (British Columbia) to the existing railway system in Russia and China via Fairbanks; a tunnel under the Bering Strait; through Eastern Siberia and on to interchanges with the 5 foot gauge B. A. M. and Trans-Siberian Railroads and then to connection with the standard gauge railways of China. The connection to China



Rail Yard in China.

accesses 54,000 kilometers of standard gauge line in China. This in turn gives access to the standard gauge systems of Korea and Northern Vietnam. Underwater tunnels connecting to Japan are a future possibility. The length of the railroad line from North America to Russia and China is about 4,500 miles.

The Intercontinental Railroad would integrate the transport systems of several powerful economies and existing transport markets. It is currently estimated that the freight volume between the Orient and destinations in North America is between 500,000 and 600,000 containers per year. Since east-west distances via the Bering Strait are much shorter than the existing overland and sea line routes, much transportation time will be saved as well as two land-sea transfers. This is additionally true because the running speeds of modern trains are considerably higher than ocean ships. Indeed, using the northern route, as the airlines do, the Intercontinental Railway via the tunnel under the Bering Strait would shorten the transportation distance between many transport, industrial and agricultural centers in North America (U.S., Canada, Mexico) and those in the Orient. For example, the distance between the grain loading point in Kansas to a destination, say in Bombay, is much shorter via land through the Bering Strait than the current transport line via a West Coast harbor. Similarly, as shown here, the transport distances via the Bering Strait, for commodities from the central part of Siberia intended for markets in the industrial heartland of the United States are nearly identical to the distance from the same area in Siberia to the Atlantic Coast of Europe. The transportation process will no longer be at the mercy of the weather and the season (sea and river ice). The other phase of the project, a line branching off across northern Siberia via Yakutsk (a major industrial harbor and river center in Siberia) and on towards Europe, to open up the vast areas of Northern Siberia for development.



Proposed rail routes on either side of the Bering Strait tunnel.

As a matter of fact, the tourism potential of the Intercontinental Railroad should not be underestimated either: the tunnel could have shuttle trains for highway vehicles similar to those now being built for use in the Channel Tunnel between England and France. Americans and Europeans with their motor homes would have the entire world open to visit so they would not all have to descend on my home town Tucson, Arizona at the same time, making city driving a real advantage. While their driving habits are objectionable to some, their spending habits are most appreciated by many. With the Bering Strait Tunnel future retirees from the U.S. Midwest could consider using their motor homes for an African safari. These tourist dollars, together with the new wealth this railroad will bring about, will enable Grandmas and Grandpas from Asia and the Orient to afford vacations in the U.S., Canada and Mexico some time in the future.

Obviously, the single most important ingredient to make this project possible is international co-operation and lack of hostilities to provide a stable base for investment in this railway and tunnel project. (text continued on page 161, project diagram foldout pg. 159)

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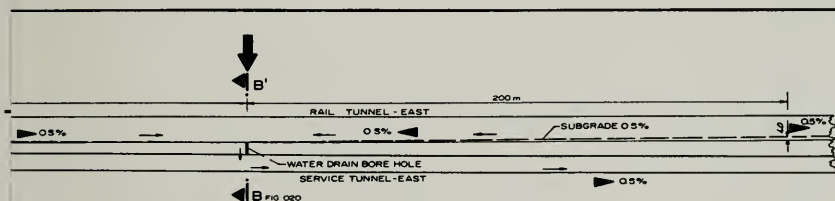
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LEGEND:

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- SURFACE VENTILATION NO UTILITY SHAFT

SEE DETAIL ON
FIG. 024



MAJOR TUNNEL SEGMENT DRIVEN ON ZERO GRADE

→ WATER GRAVITY FLOW DIRECTION

K A



TRANSFER FUNNEL TO SERVICE

DRAWING AND DUE TO
ENSIONS ARE ROUNDED

3

**BERING STRAIT TUNNEL
AND RAILWAY PROJECT**
EAST-WEST SECTION THROUGH
THE RAIL AND SERVICE TUNNEL
CONFIGURATION
BASED ON FIG. 022A.B

FIGURE 023

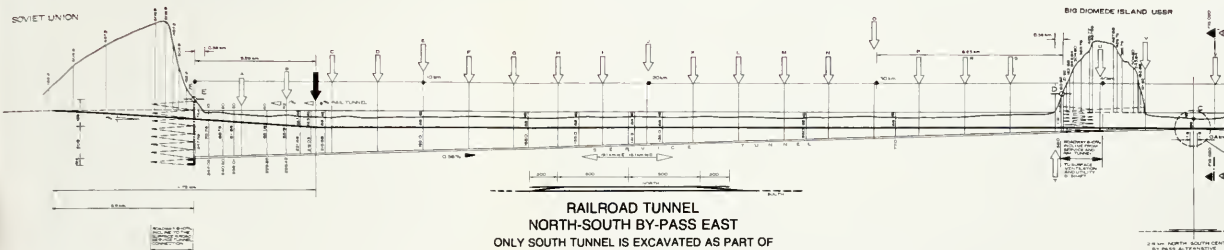
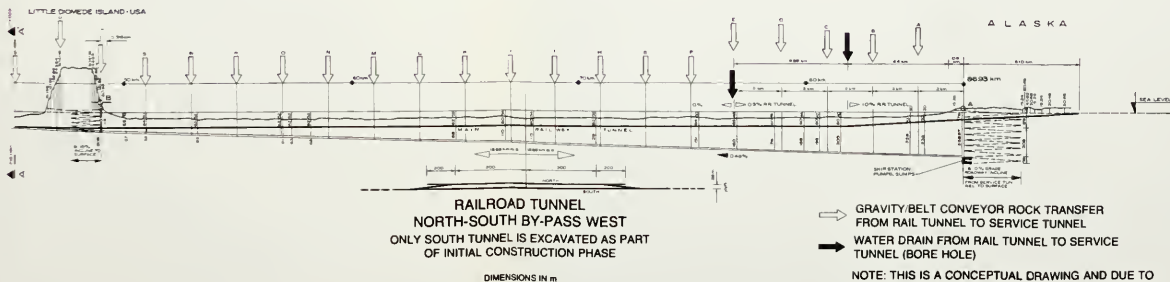
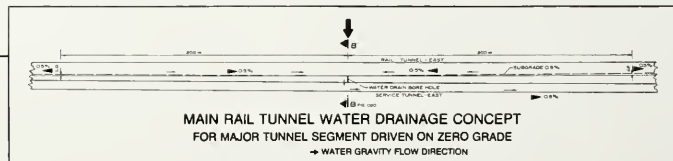


FIGURE CONTINUES FROM
THIS POINT — LOWER LEFT

SEE DETAIL ON
FIG. 024



- GRAVITY BELT CONVEYOR ROCK TRANSFER
FROM RAIL TUNNEL TO SERVICE TUNNEL
- WATER DRAIN FROM RAIL TUNNEL TO SERVICE
TUNNEL (BORE HOLE)

NOTE: THIS IS A CONCEPTUAL DRAWING AND DUE TO
LARGE SCALE, MOST OF THE DIMENSIONS ARE ROUNDED
OFF TO NEAREST WHOLE NUMBER

**BERING STRAIT TUNNEL
AND RAILWAY PROJECT**
EAST-WEST SECTION THROUGH
THE RAIL AND SERVICE TUNNEL
CONFIGURATION
BASED ON FIG. 022A,B

The Tunnel:

Experience with the conduct of underground mining operations, or underground engineering excavations in general, would teach anyone very quickly that cooperation with Mother Nature is highly recommended. She is not always readily willing to be cooperative, but it seems that in the case of tunneling under the Bering Strait, she was in a very cooperative mood indeed. She conveniently placed two islands right in the middle, between the two continents. This, of course will make the tunneling operation much easier. The islands cut the continuous under the water distance between the two continents into three sections: 22 miles from Alaska (Seward Peninsula) to Little Diomed Island; 2.5 miles between the islands; and another 22 miles between Big Diomed Island and the Asian Mainland (Cape Deznev). The longest underwater stretch is no longer than the tunnel now being completed between England and France.

In the first phase, only the service tunnel and the south track of the railroad tunnel will be excavated. The section of the main railroad tunnel will accommodate most cars used with the standard gauge, including the U.S. double stacks. To excavate the tunnels, Tunnel Boring Machine technology would be used.

Our preliminary excavation concept calls for first excavating a 6m diameter service tunnel on a .5% grade up dip from the continents to the center. This grade will facilitate gravity water drainage during excavation of the service tunnel, and later on during the excavation and operation of the rail tunnel (through drain bore holes connecting the two tunnels). The service tunnel would serve as ventilation, (text continued on next page)



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access and material movement during its own excavation and during the excavation of the main tunnel. Eventually the service tunnel will be used for inspection and maintenance of the main rail tunnel.

Water drain bore holes will be placed at 400m intervals. Raises will be bored every 2000m (2km) between the two tunnels for access, ventilation and material movement (cut rock during the excavation phase in both tunnels.)

Our preliminary geological data shows that granite massive forms the sea bed of the relatively shallow sea between the two continents. The maximum water depth of 54m (177") is between Little Diomed Island and the Cape of Prince of Wales on Seward Peninsula. This is not as deep as the deepest point in the English Channel. Solid rock between the top of the tunnel and the sea floor is to be a minimum thickness of 65m.

To ease the potential traffic logistics of a single bore main railroad tunnel, a length of the north track of the tunnel will be excavated, midpoint between the continents and mainly under the two islands. On the main tunnel section, a permanent rail installation will closely follow the excavation face. Main tunnel excavation crews, as well as all supplies, will be delivered to the face by conventional rail cars.

The undersea section of the main tunnel will be excavated on a horizontal grade with a water drain subgrade maintained through the floor lining. Tunneling from the surface elevation to the undersea tunnel level will be done on a grade not exceeding 1%.

Part of the gravity water drain concept described earlier is the establishment of pump systems on both continents near the shafts. These installations will be accessible by wheeled equipment from the surface.

(text continued on page 164)

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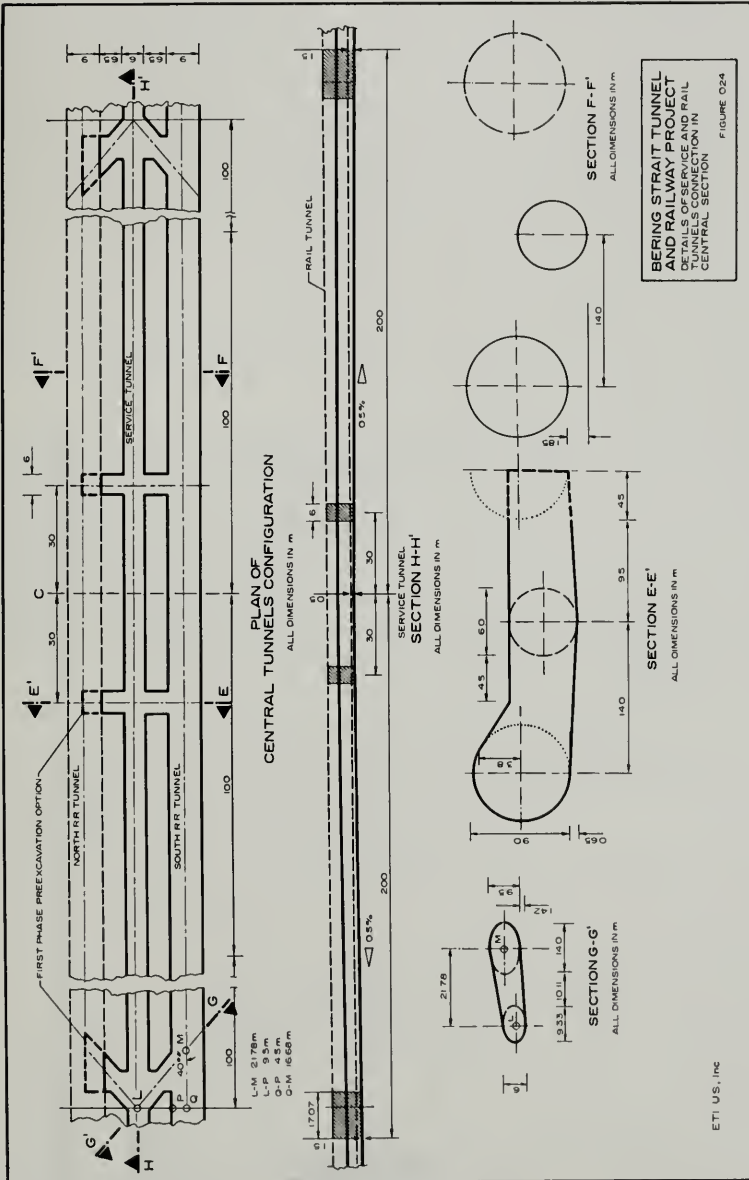
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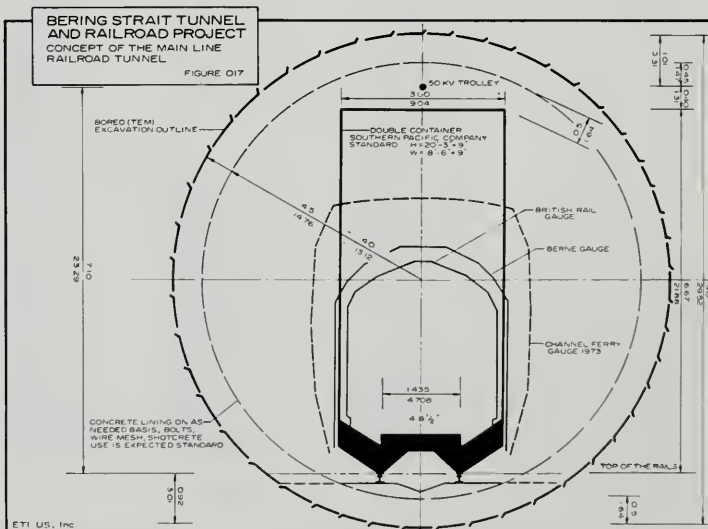
Project Cost—Financing:

Based on the project description above, we have established the construction cost to be around 27 billion for the connection of the North American and Asian railway networks via a tunnel under the Bering Strait, out of which 15 billion is for the tunnel. This estimate is in 1987 dollars and it is very preliminary. To arrive at this estimate, we used \$18,000/ft as an average unit cost for tunnels, and between 2-3 million per mile of railroad, plus costs for needed shafts, inclines, or for special construction steps required to safeguard the all year round construction process. The stretch through the tunnel would need to be electrified. It should be noted that this is not an Arctic project, as the tunnel and the railway will continually be south of the Arctic Circle. The expense is considerable but we think that the value of potential benefits more than matches the expense. The cost is only about 5% of what the U.S. and Russians paid in yearly armament expenses as recently as five years ago.

We expect that, while some initial financial stimulus will have to come from the governments involved (U.S., Canada, Russia and others), the key financial resources will come from the private sector. The proven checker board pattern of mineral and land ownership rights along the railroad right-of-way can be used. To prevent the Russians' fears of selling Mother Russia to foreigners, three forms of this ownership can be adopted: Russian/U.S./Canadian Government, Russian/foreign private ownership, and foreign private ownership.

The sale of land and mineral rights along the railroad, 50 miles on each side, say for example between the Bering Strait and Central Siberia as shown on this slide at a fair price of \$500 per acre would generate some 67 billion. The railroad would cross several oil fields and there the price per acre would be higher.

In summary, this railway project is feasible from an engineering standpoint. The tunnel from Alaska to Siberia will not have any length continuously under water greater than the English Channel tunnel, and it will be no deeper than the channel tunnel. Because the line would initially be single track, the length of track tunnels would be about the same as the channel tunnel. In addition the railway line would not have to exceed 4000 feet in elevation on the Russian side. It would not be North of the Arctic Circle, while several heavy duty railways already exist at locations North of the Arctic Circle. So the new line would not require anything unprecedented.



Bering Strait Tunnel Cross Sectional Dimensions.

Using double stack trains the line would connect North American and Oriental markets using a shorter route than boats and with faster running speeds than by boat plus saving two rail-water transfers. It would finally connect the Alaska Railroad with the rest of the North American System. It would give people the option of driving almost anywhere on earth using shuttle trains through the tunnel and it can develop the mineral resources of Northern Siberia.

If present political trends continue and provide a growing global market and a stable political base for such massive projects as this, I believe this project will be a reality in 10 to 20 years, greatly expanding the horizons of North American Railroading and the A.R.E.A. Several railroads have already appointed people to be contacts on this project, and if any other railroads, consultants or government agencies wish to be involved in the group considering the tunnel, please contact me or A.R.E.A. headquarters. Thank you for your attention.

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AREA PRESIDENT'S ADDRESS

By: Ernest J. Rewucki*

I am very pleased to have the honour of addressing you today as President of this Association and to share with you some of the key issues that AREA has had to deal with over the past year, and also some of the challenges that we in the Railway industry will have to face if we are to remain viable as we face the challenges of the nineties.

Firstly, the Association is healthy. Although we have seen a slight reduction in railway members, the total membership has held steady at just under 4,000 members, although the membership has become increasingly varied. Last November when we looked at the make-up of the membership we found that only about 45% of AREA members were employed by Railroads. Now this should not be alarming as it is only a natural consequence of railroads having more of their engineering work done by engineering consultants. Thus, it is not surprising that now 25% of AREA members are contractors or consultants.

In most recent years we have seen a tremendous growth in the transit industry in North America. In fact, today 6.5% of AREA members are employed by transit or passenger railroads, but this certainly represents a minority of those AREA members primarily involved in transit because a higher percentage of their engineering work tends to be done by consultants. To acknowledge the increased role of rail transit, the AREA Board voted Saturday to submit to the members an amendment to the AREA constitution that would allocate at least one position on the Board from an employee of an urban and/or suburban rail passenger railroad. This will assure that AREA members from rail operations such as the Chicago Transit Authority or Metro North Commuter Railroad will have a better opportunity for election to the AREA Board of Direction. You will be getting your ballot on this issue in the next month or so if you are an AREA voting member.

You probably are aware of the fact that last year the AAR carried out a review of the Operations and Maintenance committee structure. As a result of this review the various AAR committees were reduced to about half which will result in substantial savings to the member railroads of the AAR. The AAR study did not of course deal with the AREA Technical Committees as the AREA Committees are not controlled by the AAR.

I did however, receive a letter from Jim Hagen, Chairman and Chief Executive Officer of Conrail who also acts as Chairman of the AAR, recommending that the AREA undertake a study of its Committees as had been done by the AAR for their committees in the mechanical, signal, transportation, safety and other areas. The AREA sees value in such a review because we are confident of the overall value of the AREA committees to the AAR member roads, and we want to make sure that the AAR railroads are getting the most out of the money and time their employees are spending participating in AREA committees.

In doing this we realize that the AREA committees have many important roles in addition to their service to the AAR Committees, such as rail transit and high speed rail, which have a limited direct benefit to the AAR roads and so participation by AAR freight roads would be expected to be limited but this in no way means they are not very active committees and important to our railway engineering profession.

Even committees that do benefit the AAR railroads directly (in the sense of relieving the AAR of the need to have its own committee on the subject) such as the crosstie, rail and bridge and building committees, also have many important functions that serve non-AAR purposes.

AREA committees have many members in some cases the majority of members are not employees of railroads, and this is often entirely appropriate, and needs to be acknowledged, especially as many railroads have more and more engineering work done by outside consultants. Final approval of manual and portfolio changes, however, remains with the Board of Direction, who according to the AREA Constitution, must be AREA members, employed by railroads, since railroads are the final users of the

*President, American Railway Engineering Association, 1991-1992, Chief Engineer, CP Rail

engineering and materials involved. The AAR member railroads can be assured that their interests and the interests of the AREA are mutually supportive and that other AREA activities are either non-related or complimentary, but never in conflict. Many of you will probably get involved in this study of committees, and it will probably take some extra time, but I think the results will be worth it.

We look forward to improvements in our committee organization:

- in terms of efficiency in utilization of railroad employee members.
- in terms of expansion to serve the growth in various areas of the rail mode.
- in terms of providing more opportunities for member participation, and,
- in terms of reducing those specific details of committees which the changing times have rendered no longer of value.

Now, if I may, I would like to talk about some of the challenges we in the Railway industry will be facing in the next decade. First a little background.

As you know the Railway Industry in North America has gone through a significant transition in recent years. Global competition has forced governments to de-regulate freight rates. On the other hand, in response to new social pressures like environmental and safety concerns, governments have re-regulated many of our practices and procedures to conform to more stringent standards.

The enactment of the Staggers Act in the U.S. and the National Transportation Act in Canada has forced railways to improve their efficiency and productivity in an environment dominated by market forces.

The Canada-U.S. free trade agreement is a two-edged sword for many North American railways. Although it will accelerate North/South economic integration, it will also bring about shorter hauls for many railways.

In the next decade, North American railways will have to respond aggressively to take advantage of the evolving economic, political, regulatory and competitive environment. In particular, it calls for continuing rationalization of the railway plant and reduction in staff in order to drive down costs to meet increasingly severe market conditions and re-regulatory pressures.

The railway industry is seeing significant market share erosion due to changes in traffic patterns and competitive strategies from highway trucks, shipping and pipelines. To survive and grow, railways must respond aggressively to overcome these competitive forces.

The challenges, therefore, for the railway industry managers in the 1990's are to:

- recognize that the ultimate performance measurement is the ability to service the company's customers in the most cost-effective and reliable manner;
- improve productivity on all projects through "smarter" work methods and more cost-efficient technology;
- reduce costs on all work through tighter cost/benefit screening of projects, and by eliminating waste and redundancy;
- determine the optimum cost effective material specification and design;
- meet or exceed the requirements imposed by regulatory authorities and our own high safety standards.

Social pressures, like environmental and health and safety, are increasingly dictating the concerns of public policy makers around the world. These issues are expected to remain amongst the highest priorities of all levels of governments throughout the 1990's and beyond.

The challenge, therefore, for railway management in the 90's is translating these pressures into policies that make assuming social responsibilities sound business sense. In other words, how do we respond to competition driven by de-regulation, and social responsibility driven by de-regulation?

Environment

One of the most important issues that Railways will have to face in the nineties is environmental issues.

Most consider the environment to be the most important issue facing the world. Most think the environment has worsened over the past few years.

Environmentalists are applying pressures on railways for pollution controls, spraying of insecticides and vegetation control agents, noise and the carrying of dangerous commodities through populated areas, etc.

The regulatory agencies are reacting to the pressure. Environmental regulations are affecting more and more of our activities, and becoming more stringent.

Corporations are also getting on the bandwagon. We, at Canadian Pacific, are committed to protecting the environment. To be effective we have to address three primary areas of responsibility. These are the legal responsibility to obey the laws of the land; a Corporate responsibility to address the concerns of the Public; and a responsibility to provide a safe work environment to Company employees.

At CP Rail we have developed an Environmental Management Strategy. The major objectives of the Strategy are to increase the awareness of environmental matters within CP Rail - System and to identify and execute the steps necessary to minimize the risk of environmental problems and the associated potential liability.

Technology

Let's look at some of the technological challenges facing the Railways.

The use of some of the emergent technology will enable railways to reduce cost and improve reliability. Technology will affect us in the sphere of operations as well as in the planning and control functions.

Although we tend to think of planning in terms of major renewal programs such as rail, ties, surfacing and ballast because of their major effect on our costs, we must think of planning at all levels of operation and supervision.

Clearly one of the keys to remaining competitive has been to build a track structure that will support traffic at a low unit cost. Efforts to produce track that is matched to the load started in the late 60's.

Increasingly, computerized track inspection technology, for example, the Track Evaluation/Geometry Car, is being used to perform technical and economic assessment of maintenance of way projects.

Right across North America we have seen a dramatic reduction in rail failures, track surface errors, and we have been able to show a real benefit from conversion to heavier weights of rail, the use of hardwood and concrete ties and the adoption of a tighter ballast specification.

These improvements have been achieved at varying rates by all major North American railways, with the happy result that track-caused derailments have been declining progressively.

What does better track mean to us? Well, it is cheaper track to maintain, allowing us to price more competitively. It causes fewer train delays, allowing us to provide better service to the customer. But most importantly, it is a safer track.

Our long standing efforts to produce a better track structure have certainly given us more room to maneuver in this competitive environment and has allowed us to meet our obligations regarding public safety.

At the same time, we cannot afford to provide a first class track structure over all tracks. Track must be closely matched to traffic service, within well defined standards. In today's competitive environment, we are challenged to ensure that we spend our M/W dollars in the right place, and at the right time.

We spend a great deal of money maintaining track. The value of even a 5% improvement in the service life of track components is important to the bottom line. For example at CP, we could save \$20,000 for each mile of rail in our new rail program whose replacement we can defer just one more year. There are a great deal of potential savings in just being more precise in our evaluation of the economic renewal timing of all track components in our thousands of miles of track across North America.

This precision requires some heavy duty assistance to the overworked M/W officer. We, on CP, have therefore, invested in a major program to develop improved automated track inspection data—and to back it up with computerized planning assistance.

This assistance consists of predictive models of plant deterioration that will help railways determine the optimal time to replace a physical plant element, like rail, tie or ballast. You will hear a lot more on this subject on Tuesday morning, when Mike Roney, from CP, will describe to you how our system works.

The systems that are now under development will be used to plan our rail, tie, surfacing, rebalancing programs. When all costing routines are complete, they will give our people a powerful calculator to trade off the economics of different maintenance strategies. But perhaps, of most importance it will assist us to answer our marketing people with maintenance programs that will anticipate the appropriate response to traffic shifts and have the right track in place at the right time to serve the shipper.

The reduced revenue expected in the 1990's from that realized in the 1980's, with at the same time an increase of traffic simply means that less money is available but more maintenance work must be done. To further complicate the picture, traffic will not be able to withstand the same delays. Therefore, the work windows, or time between trains in which work can be performed, will be shorter, and there will be fewer of them.

We have to change our thinking. In the 1980's gangs became larger than the 1970's, and required long work blocks to be most effective. So, we now have to look at what is smaller or more productive and can be efficient in short work windows.

Large gangs tend to take up longer track time to get to the work site and to start up while the back end waits for the front end to complete the 1st tasks. Productive work may then take place quickly, but a lengthy shutdown which is the reverse to start up also takes place at the end of the work block to clear a train. We therefore, have to look at gangs that do not require long blocks to be effective, because, while their productive rate per hour may not be as great, they have quick start up and close up times. Such gangs will generally be smaller and will either run to the work site at high speeds and start up quickly or set on and off the track where they are working. These less complex gangs will certainly be easier to more skillfully manage and may accomplish more in their productive work hours than what is now anticipated, driving down unit costs even more.

The importance of assigning the right equipment that matches the other equipment on a gang is also important. Gangs are like an automobile assembly line except the workers and the machines move while all the cars stay still. All work stations must work efficiently with none holding up the other. The equipment therefore, has to be chosen carefully, and it must be reliable. We must work closely with Railway Equipment Manufacturers to constantly investigate, assess and assist in the development of new and better equipment.

On CP we are in the final stages of development of a computer simulation model that will predict what will happen with an infinite combination of gang types, sizes and make-ups, with various work blocks, tied in to train scheduling. This model is only part of a Work Program Planning System being developed by our Industrial Engineers that will help our maintenance of way supervisors schedule our work programs so that we cause minimum disruptions to our train operations.

What I have talked about today, will result in improved reliability of service to our customers, improve productivity and reduce costs, while at the same time exceed or meet the regulatory requirements.

Information and technology is available today, as never before. The use of available planning methods and management systems will ensure optimum performance is obtained in the maintenance of our track, the revenue traffic on it, and will ensure the long term viability of the railways.

However each Railway can't do it alone, but I am confident that if we all work together through our technical committees of the AREA we will be able to face the challenge of change head on. But we will need help, and this is where the research and testing activities of the AAR Research and Test Department in co-operation with the various railroads and suppliers come into the picture.

The relationship between AREA committees and the AAR Research & Test has been excellent, and strong links of communication are in place to see that AAR research funds are spent in the most meaningful way for the optimum combination of problem solution and innovation in railway engineering. Much has already been done in the past, but much yet needs to be done, in order that railway engineers may base their engineering and economic decisions on proven facts rather than simple experience alone or tradition.

The AREA Committees are eager and ready to co-operate with the AAR Research & Test Department to develop the data bases on which railroad engineers can base their decisions. We realize that research funds are limited, and that not all committees have gotten their research priorities, but this is usually a matter of when priorities from other areas, including other than track and bridge, take precedence to cause a better utilization of research funds from an overall railroad standpoint.

At this time, I would also like to acknowledge the efforts and to express the appreciation of our Association to our many good friends in the supply industry and REMSA for your excellent co-operation during the past year, and for your help in the development, testing and the research you have done that has led to the improvements in techniques and machines that we so critically need to improve the efficiency of our maintenance of way practices. At times we in the Railway industry may seem impatient that progress in the development of new, more effective materials and equipment is not happening fast enough, but I know that those in the Railway Supply Industry are just as anxious as we are to continue to work towards developing new techniques and machinery that we so vitally need if we are to keep competitive in our industry.

In closing, I wish to express my appreciation for the co-operation and the hard work performed by the AREA officers and the Board of Direction. I also commend our Technical Committee Chairmen and all the Committee members who worked so hard to perpetuate the excellent reputation and leadership of the AREA in the railway engineering and maintenance field. Without such support, the desired results could certainly not have been obtained.

No conference can proceed as smoothly year after year as this conference does without a lot of hard work by many people. I wish to convey to the entire Conference Operating Committee our appreciation and thanks for an outstanding job.

My personal thank you to Lou Cerny, Tom Smithberger, Wendy Tayman and all of the Washington staff for your able assistance in all phases of our work.

And finally, I wish to express my sincere appreciation for the privilege and honor of serving as President of your Association. It has been a very rewarding experience and certainly a highlight in my career.

Thank you.



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HIGH SPEED TURNOUTS ON AMTRAK

By: A. E. Shaw, Jr., P.E.*

Members and Guests of the AREA:

I welcome the opportunity to appear before you today and share information about Amtrak's new Hi-Speed Turnouts.

In connection with the upgrading and electrification of the double track line between New Haven, Connecticut and Boston, Massachusetts, Amtrak is purchasing sixteen Hi-Speed Turnouts to be installed as crossovers for four Universal Interlockings. To my knowledge, there are no turnouts or crossovers in the United States which have speeds higher than fifty miles an hour even though, years ago, there were some No. 24's and No. 30's which were probably designed for 60 mph to 70 mph.

In 1986, Amtrak installed outside of Washington, D.C., a No. 30 crossover based upon European design very similar but somewhat different in geometry from those used on the French TGV line. This Amtrak crossover has performed satisfactorily and became the basis of our design for new 80 mph ones. The crossover we installed in 1986 was designed for 70 mph with 3" underbalance and no superelevation through the turnout side.

Criteria stipulated for the new crossover design is: speed—80 mph at a maximum of 2-1/2" cant deficiency, which resulted in a 10,116 foot radius turnout with a No. 32.7 straight frog. This large radius turnout insures a very comfortable ride for our passengers. The low lateral acceleration of 0.044 g's is due to the low cant deficiency which equates to low maintenance and long wear.

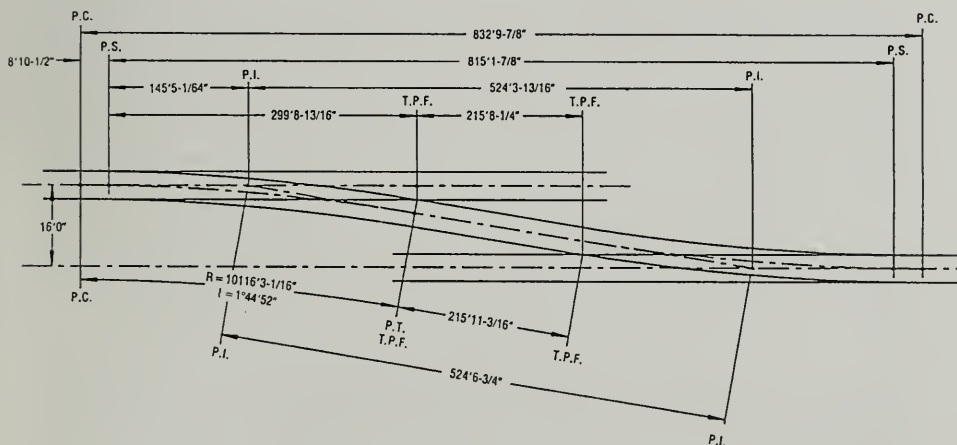


Figure 1. Amtrak 80 mph tangential geometry crossover.

In a comparison of the Amtrak turnout and several European high speed designs, the speed on the European turnouts are somewhat higher at 100 mph vs. 80 mph for the Amtrak design, but car lateral acceleration on the Amtrak design is somewhat less. The crossover configuration was the same in all designs being for 16 feet track centers.

Amtrak's turnout geometry is a simple curve with a tangent point approximately eight feet ahead of the point of switch and extending to around eight feet ahead of the point of frog. This tangent then extends through the frog towards the turnout in the opposite direction. Since the frogs are straight and have no slip joints, they have no hand, thereby reducing inventory needs for spare parts. The frog points are well

*Director Engineering Tests & Standards, Amtrak

housed into the frog wings to protect points from wear at the thinnest part. Each frog point has two electric switch machines to drive it even though it had been hoped that one machine would be satisfactory. Calculations indicated it was necessary to have two machines, and to further substantiate this, a model was built and tests were run to verify two machines being required.

Country	Turnout Radius (ft.)	Point of Switch to Point of Switch (ft.)	Maximum Theoretical Lateral Acceleration (g's)	Speed (mph)
Germany (DB)	12,136/19,680	943	0.054	100
Spain (RENFE)	12,838/32,808	994	0.050	100
France (SNCF)	9,624	962	0.066	100
USA (Amtrak)	10,116	815	0.044	80

For: Track Centers 16 feet

Table 1. Comparison of High Speed Turnouts (Crossovers)

Most European moveable point frogs as well as the ones installed by Amtrak in 1986 have what is known as a "clamp-lock" system for locking the frog points rather than have locking in the switch machines. While this system works satisfactorily, maintenance was high. Therefore, we have elected to have all the locking in the switch machines with point detection similar to what is on a switch point. The connection for switch machines to the frog point has been one problem which I hope we have overcome, but so little is known about these devices in the United States only time will tell. Numerous different types of connections throughout the United States with different ideas were looked at and from these evolved a design we intend to use.

The moveable point frog is fastened to the concrete ties with cast in Pandrol shoulders, "e" clips and 9mm rubber pads between the base plate of the frog and the concrete ties. This is a departure from most installations that I have observed in the United States which use screw-type fasteners. However, it isn't completely novel: Australians have used something similar, and in Zimbabwe, I have seen pictures of a similar installation.

The moveable point frog is a fabricated-type utilizing an all-welded point and 140 lb. wing rails, with the whole assembly mounted on a 1" base plate. The combination of the 140 lb. rail and the base plate would make the frog assembly 1" higher than the rail adjacent to the frog. Therefore, the concrete ties in the frog area have a raised boss opposite the frog on either side to eliminate the need for steel plates under the running rail to equalize the thickness. This not only eliminated need for the steel plates, but also eliminated more screw-type fasteners as Pandrol shoulders are cast in throughout this area as well.

We have been very satisfied with the tangential geometry of the crossover installed in 1986. Several years ago, the AAR with their NUCARS computer simulation program compared the Amtrak No. 20 geometry turnout, which is similar to AREA's, with a tangential No. 20 geometry turnout having a lead length about the same as the standard Amtrak No. 20 turnout. As expected, the radius being somewhat less on the tangential geometry turnout because of no switch angle, resulted in peak lateral forces being considerably less but with average lateral forces becoming slightly higher. Also, the predicted wear life of the tangential geometry turnout is longer than for the Amtrak standard geometry, and peak lateral accelerations were also predicted to be considerably less than for the tangential design.

This looked encouraging from a maintenance standpoint as well as a ride comfort standpoint, and with the proven success of the crossover installed in 1986 and the experience of all-European high speed railroads, it led us to choose tangential geometry for the new design. The switch points on the new

turnouts are approximately 130 feet long and are made of the Zul-60 asymmetrical rail section. At the heel end of each switch point, the end of the Zul-60 rail is upset forged to a cross section approximating that of a UIC-60 rail section. The 140# rail to be joined to the switchpoint is also upset to approximately a UIC-60 rail section as well, and the two sections are then flash butt welded together. These flash butt welds upon completion are carefully ground and ultrasonically tested.

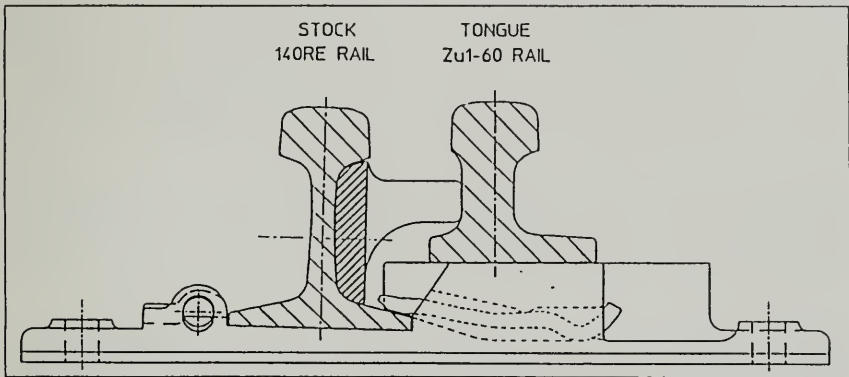


Figure 2. Cross Section of Amtrak Asymmetrical Switch Point and Stock Rail in Turnout

An advantage of the asymmetrical switch point design is the lessened height of the switch rail, which sits on a raised switch plate. The switch plate has a groove in its edge for the stock rail to fit, preventing rail turnover without the use of heavy braces on the outside of the stock rail. The outside of the stock rail is secured in place with only a "e" clip on each tie. The inside of the stock rail is secured to each tie with two spring clips, each having approximately half the total load of the single "e" clip used on the outside of the stock rail. The stock rail can be removed easily by removing the inside and outside clips and just rolling it out. Stock rails as well as all rails, except for the switch points, are canted 1:40.

The only screw fasteners used in the entire turnout are those which secure the raised switch plates to each concrete tie. Each switch plate is fastened with four screw type fasteners into respective female inserts cast into the tie with 9mm rubber pads between the top of the concrete tie and the bottom of each switch plate. These fasteners are made by The Vape Company. As the loading of each of these screw fasteners is very critical, it is intended the plates will be fastened to the tie at the point of manufacture to minimize the need for Amtrak personnel to change the torque on any of the screw fasteners. Each switch will have three electric switch movements to properly throw the switchpoints. The switch machines are mounted on steel extension plates, fabricated and bolted to the sides of the respective ties. This method of installation allows for flexibility using different types of switch machines and is the method used by Amtrak since its first concrete tie switch installation in 1985.

The rods used throughout the switch points are the same as those used in our No. 30 crossover installed in 1986, being especially made for each location and non-adjustable. The baskets on the respective rods where there are switch machines are standard American manufactured baskets as is the insulation used on all of the switch rods. The switch rods with baskets are designed so that the standard Amtrak operating rod may be used. As the switch points are different from a standard AREA type, the point connections and lock rod connections are modified slightly so that a standard Amtrak point detector and lock rods can be used. As no gauge plates are used, there is no need for insulation at these particular locations.

Eventhough the three concrete tie turnouts Amtrak has had in service for several years had tie spacing approximately the same as wood tie turnouts, it was felt that the tie spacing in the new design should be at

24" and this was confirmed by the concrete tie manufacturer's design. The slightly increased tie spacing allows easier adjustment of switch rods, baskets and any other component which may be in the cribs between ties. In addition, the wider spacing means less ties overall. This reduces costs, and since there are slightly less ties in each crossover, there is less tamping needed. Furthermore, it is felt that the more uniform tie spacing will result in a track modulus more similar to track either side of the turnout.

As we wanted to use a slightly heavier duty insulator than those used on concrete cross ties, the Pandrol HD10 insulator was selected. In addition, the pads used on concrete switch ties, other than those under the frog and under the switch plates, were purposely made somewhat thicker so there could be no confusion on mixing them up with those on concrete cross ties. The HD10 insulator is considerably different in appearance than the ones used on standard cross ties so that there cannot be accidental mixing between them. Pandrol "e" clips are used throughout and they are identical on the switch ties as well as on cross ties. The rubber pads used throughout the turnout installation are the same as those used throughout most of the North American railroad industry on concrete tie turnouts. They are also the same ones used by Amtrak in prior concrete tie turnout installations all of which have performed well on Amtrak, and to my knowledge, on other railroads as well. The Vape fasteners were selected because the threads were of a type to resist unscrewing compared to others on the market. Two of Amtrak's concrete tie installations have used these with satisfactory results so far.

All joints throughout the turnout will be welded with the exception of the four at the frog and the two on ends of switchpoints. These joints will be glued using "D" bars, with a bonded joint procedure for gluing in the field or at track side prior to installation of the turnout.

In order to prevent nuts and bolts from loosening, all nuts and bolts throughout each turnout will be secured with self-locking nuts or slotted nuts and cotter keys. All nuts will be tightened to structural tightness, with as many as possible being tightened at the point of manufacture or assembly prior to delivery to Amtrak.

When Amtrak went out for bid for the sixteen turnouts, the specifications required that the switchpoints be manufactured from one piece of rail, and although the specification didn't specifically require the Zul-60 section be used, all of the bidders on the job bid to use an asymmetrical switchpoint rail section. There is no rail manufactured in North America longer than 80 feet, nor is any asymmetrical rail used for switchpoints rolled in North America.

Most of the moveable point frogs so far installed in the United States have been manufactured outside of the United States. Therefore, it is understandable that the successful bidder on our job was a partnership of Bethlehem Steel Company and the English company Balfour Beatty.

The switchpoints, switchplates and frogs will be manufactured in England and the balance of the steel parts will be manufactured in the United States. The concrete ties are being manufactured by Sherman Abetong Company in Ohio as a subcontractor for Bethlehem. The Bethlehem facility in Steelton will be used to assemble all components.

All parts will be match marked with assembly video tapes being made. The turnouts will be partially disassembled for ready shipment to Amtrak via railroad car. Amtrak will reassemble each turnout as close to the job site as practical and each will be installed in several panels. Presently, most of the engineering is completed and the turnouts are expected to be delivered in 1992.

FATIGUE OF STEEL BRIDGES

By: Kenneth E. Bruestle* and Zolan Prucz**

1.0 INTRODUCTION

The continuing trend toward heavier freight cars and trains has raised concern in the railroad industry over the fatigue condition of the large number of older steel bridges in service. The majority of these bridges were built before adequate fatigue provisions were available in the code. Burlington Northern Railroad shares this concern with the rest of the industry.

Burlington Northern Railroad is a heavy haul freight railroad which operates primarily in the western half of the United States. It operates over approximately 25,000 miles of track, and owns and maintains about 11,000 bridges. Of these bridges, 5,050 are timber, 2,600 concrete and 3,350 steel. In general, the steel bridges are older and more valuable than the timber ones. Also, they comprise nearly 50% of the total bridge length. Prolonging the safe useful life of the steel bridges is of primary importance. The majority of the steel bridges owned by the Burlington Northern Railroad were built in the early part of this century. The oldest documented construction for a span is 1879, and the mean construction date of all steel spans is 1933.

The loading of railroad bridges has been constantly increasing over the years. Also, the mix of traffic has been shifting toward unit-type trains consisting of a large number of heavy, fully loaded cars. The present and future trends are toward even heavier cars. Burlington Northern is using larger locomotives and hauling unit trains of coal and grain. It has been ordering new grain cars with 286,000 lb gross weight. In addition, heavier than normal axle loads are produced by the articulated trucks of the double stack cars.

All of the Burlington Northern bridges are presently in safe operating condition. This is ensured through periodic bridge inspections. Every bridge is inspected at least once annually. Many are inspected much more frequently, such as the Latah Creek Bridge in Spokane which is looked at quarterly. Corrosion does exist to some extent on a number of Burlington Northern bridges, but it has not been a major problem. Structural obsolescence and accumulated fatigue damage are now becoming the major concerns. In order to establish where Burlington Northern is in the fatigue life of the steel spans, Burlington Northern engaged Modjeski and Masters to develop a fatigue damage assessment procedure.

This paper describes the development of fatigue loading histories for bridges on the main lines of the Burlington Northern Railroad and the formulation of a computerized fatigue damage assessment procedure that uses the traffic data collected.

2.0 LOADING HISTORIES

Current AREA specifications for design provide for appropriate fatigue lives for new bridges but are not suitable for assessing the fatigue condition of existing bridges. In order to determine the remaining fatigue life of an existing bridge knowledge of the loading history of that bridge is needed. Historical loading information has been gathered in the past for the fatigue evaluation of specific bridges [1-4]. Collecting historical traffic data for each bridge evaluation and determining the remaining safe life of various bridge members and conditions can be quite laborious. It is more practical to reconstruct historical traffic data applicable to all bridges on a given railroad segment.

The development of loading histories for the main lines of the Burlington Northern Railroad consisted of a data collection phase and a data reduction phase. During the data reduction phase, the historical traffic data collected was reduced to a form suitable for fatigue damage assessments. The following routes were investigated:

1. Aurora, Illinois to Seattle, Washington.
2. Seattle, Washington to Portland, Oregon to Spokane, Washington.
3. Dilworth, Minnesota to Gillette, Wyoming.
4. Aurora, Illinois to Lincoln, Nebraska.

*Director Design, Engineering Division, Burlington Northern Railroad

**Associate, Modjeski and Masters, Inc.

2.1 Data Collection

2.1.1 Data Collection Process

The data collection process comprised the following steps:

1. Identification of the type of information needed to define fatigue loading,
2. Identification of the type of traffic data available,
3. Formulation of a data collection plan,
4. Collection and organization of the raw data.

The type of information needed to define fatigue loading consists of information related to the composition of traffic, such as type of freight cars, locomotives and trains, and information related to the volume of traffic, such as number of trains by type. The data needed to define a given train type includes information on the type (axle configuration), weight (axle load), number, and mix of the freight cars and locomotives in that train type.

The amount and the type of traffic data available depends on the time period investigated. The early data related to the composition of traffic consists primarily of chronological facts and various statistics on freight cars, locomotives, and trains. Freight car statistics, for example, include freight car weight, capacity, average loading, and relative usage for different car types. Similarly, the type, weight distribution, and relative usage of locomotives are available. For trains, the early data available consists of the type, gross and net weight, average number of empty and loaded cars per train, and relative number of trains by type. Other important data, such as the gross and net tonnage densities that are available since the early 1900's give an indication of the volume of traffic. During the last twenty years, the amount of traffic data retained has increased significantly. Railroads can now provide detailed information on the movement of trains by train type, geographical location and direction of traffic.

The composition and the volume of traffic, the type and amount of data available as well as the sources of traffic data have changed over the years. In order to account for these changes the collection of data was divided by time periods (see Table 1). The selection of the time periods was dictated by significant changes in traffic and/or sources of traffic data.

Table 1. Time Periods for Historical Data Collection

Time Period	Years
1	1900 - 1919
2	1920 - 1939
3	1940 - 1959
4	1960 - 1969
5	1970 - 1983
6	1984 - 1990

2.1.2 Sources of Traffic Data

During Time Periods 1 through 4 the routes investigated were operated by the Northern Pacific, Great Northern, and Chicago, Burlington & Quincy railroad companies. Historical records of these companies provided most of the early traffic data collected. For Time Periods 5 and 6 detailed traffic data was obtained from the Burlington Northern Railroad.

The sources of traffic data and the time periods they pertain to include:

- (a) Traffic Density Charts (Time Periods 1 through 6).
- (b) Railroad Annual Reports (Time Periods 1 through 6).

- (c) Car and Locomotive Cyclopedias of American Practice (Time Periods 1 through 4).
- (d) Burlington Northern Car and Locomotive Data Books (Time Periods 5 and 6).
- (e) Burlington Northern, OPS240-C Reports (Time Period 5).
- (f) Burlington Northern, Computer Databases (Time Period 6).
- (g) Burlington Northern, Consist Reports (Current Time).
- (h) Association of American Railroad Publications (Time Periods 1 through 6).
- (i) Knowledge of Burlington Northern Personnel.
- (j) Train Clubs, Museums, Specialty Publications.

The Traffic Density Charts show freight traffic densities by line segment and direction of traffic. The densities are given in net or in gross ton-miles per segment-mile per year.

The Annual Reports contain the following information:

- Freight Commodity Statistics (discontinued after 1975)—show yearly tonnage by commodity transported in the whole system;
- Inventory of Equipment—lists the types of locomotives and the types of freight cars in service in a given year and their number by type;
- Railroad Operating Statistics—include railroad system-wide data on the movement and the composition of trains;
- Locomotive Type and Weight Data;
- Freight Car Type and Average Capacity Data;
- Data on New Locomotives and Freight Equipment Introduced in Service.

The Car and Locomotive Cyclopedias of American Practice and the Burlington Northern Car and Locomotive Data Books contain definitions, illustrations and technical data on freight cars and locomotives in service in a given period of time.

The Burlington Northern OPS240-C Reports and the OPS240 Database contain yearly summaries of freight train operating statistics by line segment, train type and direction of traffic. The data contained on each operating segment, train type and direction of traffic includes:

- operating segment number
- beginning and ending station names
- length of operating segment
- train-miles
- locomotive unit-miles
- loaded car-miles
- empty car-miles
- total car-miles
- net ton-miles
- gross ton-miles
- locomotive ton-miles
- total gross ton-miles
- loaded car-miles per train-mile
- empty car-miles per train-mile
- net ton-miles per train-mile
- gross ton-miles per car-mile
- net ton-miles per loaded car-mile
- gross ton-miles car segment-mile
- number of trains

Consist Reports may be retrieved from the Burlington Northern computer system. They contain the make-up of a given train (type and number of locomotives, and type, number and weight of freight cars),

by train number, leaving a station at a given time. They also list the total weight and length of the train. This data is stored in the computer for a limited time only.

Publications of the Association of American Railroads, such as *Railroad Facts*, contain summaries of yearly statistical data for the United States railroad system as a whole and per district. Data such as average freight train load, average freight car load and capacity, number of cars per average freight train, and type of locomotives in service, is included.

2.1.3 Historical Data on the Composition of Traffic

(a) Locomotives

Steam engines were used during Time Periods 1 and 2 and partially during Time Period 3. The steam engine data collected included number of engines by type, total weight, weight on drivers and wheel arrangements. The weight of the steam engines increased with time at a fairly steady rate (see Figure 1). The values shown in Figure 1 were derived from the Great Northern, Northern Pacific, and Chicago, Burlington & Quincy traffic data collected. The locomotives belonging to all three railroad companies had about the same average weight distribution. The wheel arrangements of the steam engines varied, depending on the engine type, but the majority of the engines had either three or four drivers.

Diesel locomotives were gradually introduced into service during Time Period 3. Simultaneously, the number of steam engines in use steadily declined. During the first half of Time Period 3 (1940-1950), many types of diesel engine wheel arrangements were used. However, the majority of these locomotives (over 90%) were of a four-axle type. After 1950, most diesel engines built were either a four-axle or a six-axle type. The average weight of the four-axle and the six-axle locomotives stayed relatively constant.

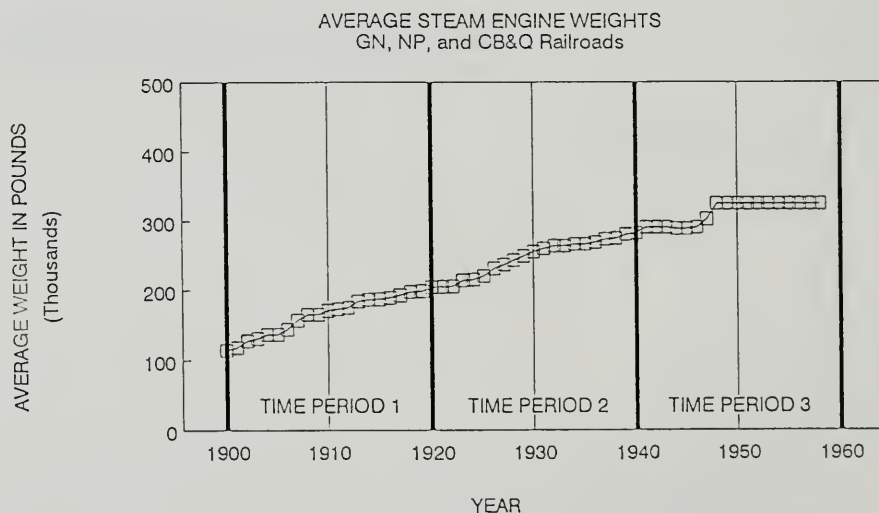


Figure 1. Changes in the Average Weight of Steam Engines (Exclusive of Tender).

(b) Freight Cars

The information collected on freight cars consisted of:

- Average Capacity by Car Type;
- Average Tare Weight by Car Type;
- Average Net Tonnage Carried by a Loaded Car;
- Dimensions of Freight Cars by Type;
- Number of Freight Cars by Type.

The freight car types considered during Time Periods 1 through 4 include box cars, refrigerator cars, stock cars, flat cars and tank cars. Data on these cars was collected from each of the three railroad companies investigated and was tabulated on a yearly basis. Figures 2 and 3 illustrate the changes in the average freight car capacity and the average net tonnage carried by a loaded car during Time Periods 1 through 4. They include Great Northern, Northern Pacific, and Chicago, Burlington & Quincy freight car data. Both the average car capacity and the average net tonnage per car have increased significantly over time. Between 1900 and 1968, the average capacity increased from about 25 tons to 60 tons, and the average net tonnage per car increased from approximately 17 tons to 40 tons. The ratio of the average net tonnage carried by a loaded car to the capacity of the car has stayed relatively constant (between 0.60 to 0.70) over the years. The freight cars of all three railroad companies showed similar characteristics.

During Time Periods 5 and 6, new types of freight cars were introduced, and some of the older car types were taken out of service. Detailed freight car data for each freight car type owned or leased by the Burlington Northern Railroad during these time periods was collected and organized.

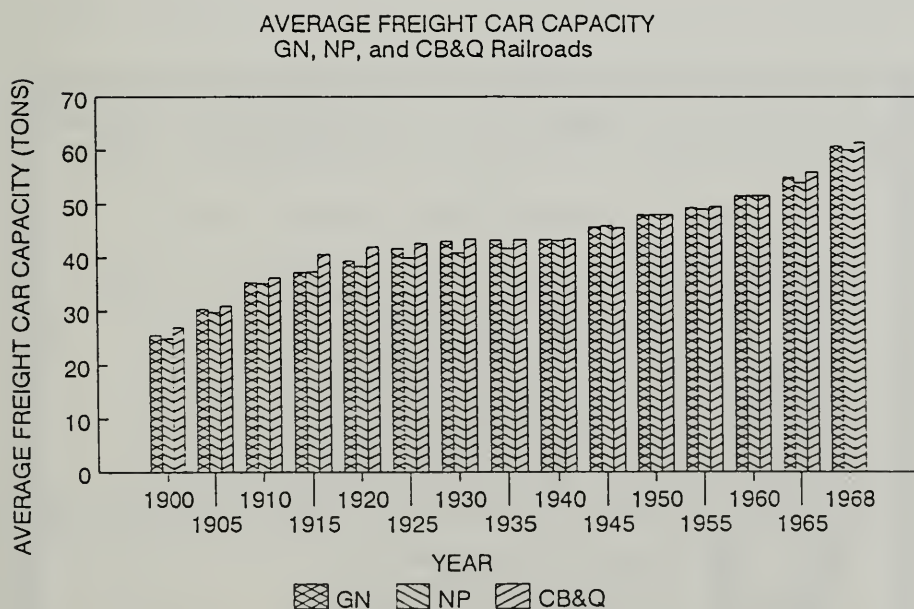


Figure 2. Changes in the Average Freight Car Capacity during Time Periods 1 through 4.

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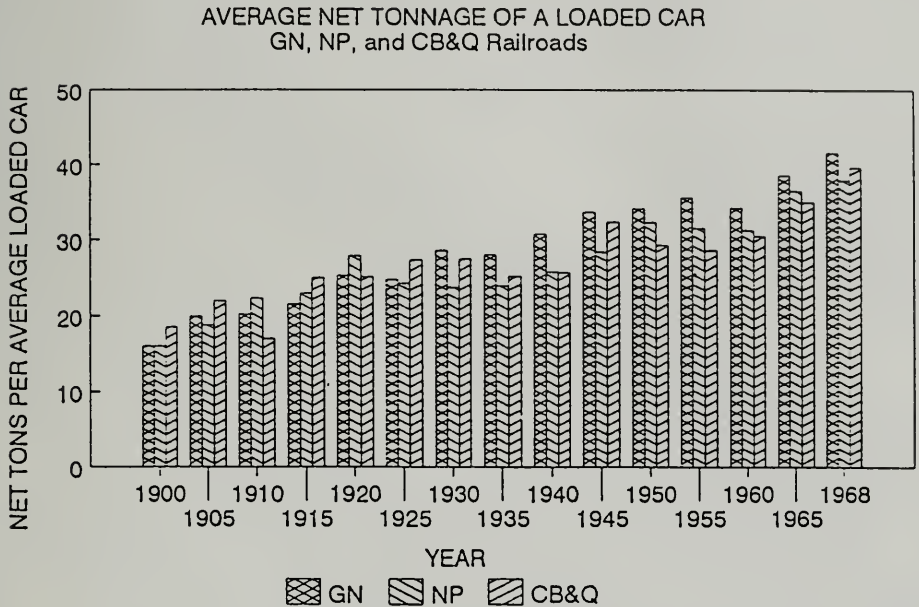


Figure 3. Changes in the Average Net Tonnage Carried by a Loaded Car during Time Periods 1 through 4.

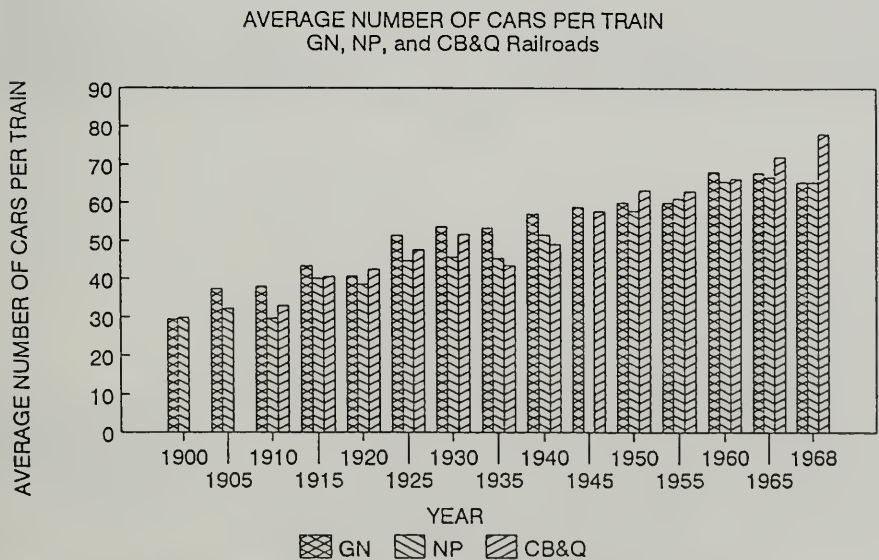


Figure 4. Average Number of Cars per Train during Time Periods 1 through 4.



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(c) Freight Trains

During Time Periods 1 through 4 trains had a mixed freight composition. The following train data was collected from the Great Northern, Northern Pacific, and Chicago, Burlington & Quincy railroads:

- Average Net and Gross Tonnage per Train;
- Average Number of Trailing Cars per Train;
- Average Number of Empty Cars per Train;
- Average Number of Locomotives per Train.

The average net and gross tonnage per train has steadily increased. Between 1900 and 1968 the average net tonnage per train increased from about 500 tons to 1,600 tons. The average number of cars per train has also had a significant increase (see Figure 4). The ratio of the net to gross trailing train tonnage has stayed relatively constant (between 0.40 to 0.50) over the years. The changes in the average number of empty cars per train is illustrated in Figure 5 as a percentage of the total number of cars per train. The characteristics of an average train in all three railroad companies are similar.

During Time Periods 5 and 6, distinctive freight trains such as unit type trains and intermodal trains became more and more common. Unit coal trains were introduced in the early 1970's and unit grain trains in the early 1980's. Double-stack intermodal traffic started in 1985 and has continuously increased ever since that time. The following data was collected for each year, train type, operating segment and direction of traffic:

- Train-miles
- Locomotive unit-miles
- Loaded car-miles
- Empty car-miles
- Net ton-miles
- Locomotive ton-miles
- Number of trains
- Length of operating segment

PERCENTAGE OF EMPTY CARS PER TRAIN
GN, NP, and CB&Q Railroads

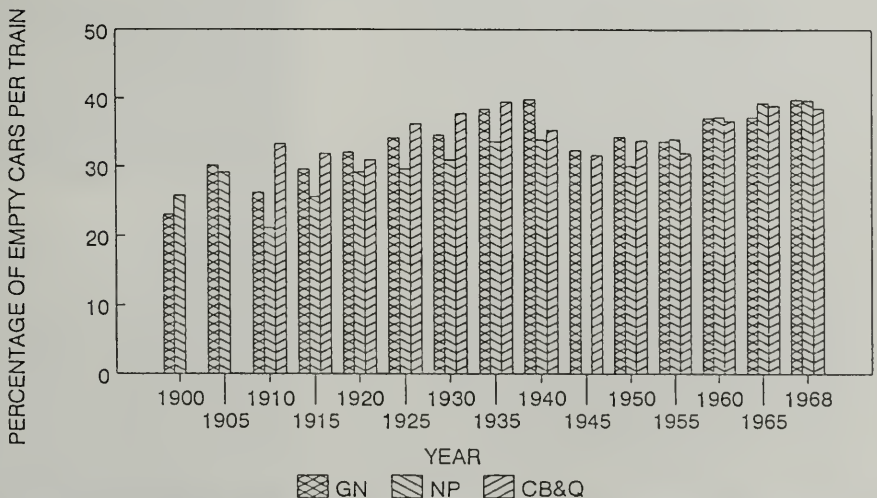
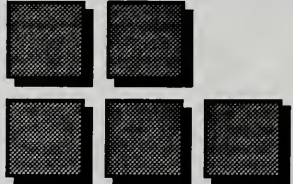
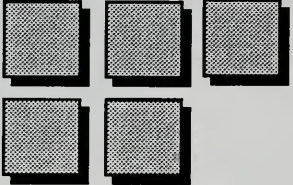


Figure 5. Average Percentage of Empty Cars per Train during Time Periods 1 through 4.

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The train types include regular freight, unit coal, unit grain, unit potash, unit ore, unit pellet, light engine, intermodal, expediter and double-stack intermodal. All data collected was stored in an easily accessible tabular form.

2.1.4 Historical Data on the Volume of Traffic

The data collected on the volume of traffic during Time Periods 1 through 4 includes:

- System-wide Traffic Densities in Net and Gross Ton-Miles.
- Traffic Densities on Individual Operating Segments in Net or Gross Ton-Miles.
- Values of Freight Train-Miles.

For Time Periods 5 and 6 detailed data on the number of trains per year, by train type, operating segment and direction of traffic was collected.

2.2 Data Reduction

The historical locomotive, freight car and freight train data collected were used to define typical train types for each time period. The data collected on the volume of traffic were used to determine the number of trains by type in each time period. The composition of a typical train was determined based on fatigue damage accumulation rules, so that the damage caused by the typical trains in a given time period would be equivalent to the damage caused by the actual trains they represent. Each typical train consists of a number of equivalent locomotive types and equivalent freight car types.

2.2.1 Typical Locomotives

Equivalent steam locomotives were determined from the steam engine data collected. The Cooper E loading was selected to represent a typical steam locomotive. Four-axle and six-axle engine types were used to represent the diesel locomotives. The typical locomotives derived to represent the locomotives used during each time period are listed in Table 2.

Time Period	Locomotive Types
1 (1900-1919)	Freight Trains, Cooper E-45 Passenger Trains, Cooper E-40
2 (1920-1939)	Freight Trains, Cooper E-55 Passenger Trains, Cooper E-50
3 (1940-1959)	Freight Trains, Cooper E-65 Diesel, 4-Axle Passenger Trains, Cooper E-60
4, 5, 6 (1960-1990)	Freight Trains, Diesel, 4-Axle Diesel, 6-Axle

Table 2. Typical Locomotive Types for Fatigue Analysis

2.2.2 Typical Freight Cars

In order to reduce the wide range of freight car data collected to a usable form, a freight car classification criteria based on axle configuration was introduced. Using the distance between truck centers as the main parameter, freight car types for fatigue analysis were defined (see Table 3). The freight car data collected for each functional car type (box, hopper, ...) was related to the car types selected for analysis. The weight distribution for each analysis car type was then determined. Equivalent car weights were computed for each analysis type car in each time period, to represent the effect of the freight car weight distribution on fatigue loading. As expected from the data collected, the equivalent car weights obtained showed a steady increase with time, and relatively lower weights for the longer cars.

Freight Car Type	Truck Center Spacing (Ft.)
A	Under 17.5
B	17.5 - 22.5
C	22.5 - 27.5
D	27.5 - 35.0
E	35.0 - 47.5
F	47.5 - 60.0
G	Over 60.0
H	Articulated Double-Stack

Table 3. Typical Freight Car Types for Fatigue Analysis.

2.2.3 Typical Trains

The typical trains constructed to represent the fatigue loading during each time period are listed in Table 4.

During Time Periods 1 through 4 one typical freight train type and one passenger train type were used in each time period.

For Time Periods 5 and 6 several typical freight train types were defined. The train types selected are consistent with the train type classification used by the Burlington Northern Railroad. Data on the number of locomotives, the number of loaded and empty cars per train and the average weight of an empty and a loaded car was derived for each time period, train type, operating segment and direction of traffic.

Time Period	Train Type	
1 (1900-1919)	Freight Train 1	Passenger Train 1
2 (1920-1939)	Freight Train 2	Passenger Train 2
3 (1940-1959)	Freight Train 3	Passenger Train 3
4 (1960-1969)	Freight Train 4	
5 (1970-1983)	Mixed Freight 1 Unit Coal Unit Grain Unit Potash	Unit Ore 1 Unit Pellet 1 Light Engine
6 (1984-1990)	Mixed Freight 2 Unit Coal Unit Grain Unit Potash Unit Ore 2	Unit Pellet 2 Light Engine Expediter Intermodal IML Contract

Table 4. Typical Train Types for Fatigue Analysis.

2.2.4 Number of Typical Trains

The number of typical trains for Time Periods 1 through 4 was estimated indirectly from the information collected on system-wide tonnage densities, tonnage densities on individual operating segments, and the average tonnage of the typical freight trains considered.

For Time Periods 5 and 6 detailed data on the number of trains by type, operating segment and direction of traffic was available.

3.0 FATIGUE DAMAGE ASSESSMENT PROCEDURE

3.1 Background

The objective of the fatigue damage assessment procedure developed was to enable Burlington Northern engineers to evaluate the potential fatigue condition of a bridge on one of the routes studied. Special emphasis was put on making the procedure 1) flexible enough so it could be updated in the future in case significant changes in the composition of traffic occur, or if new information on fatigue behavior becomes available, 2) allow for calibrations in the future, based on actual fatigue failures, 3) incorporate site-specific data derived from field measurements (e.g., actual impact factors or stresses), 4) be consistent with the AREA specifications for design, and 5) give a reasonable estimate of the remaining safe life of the bridge.

The procedure uses bridge data and traffic data collected for each operating segment and assesses the fatigue condition of a given member through the steps shown in Figure 6.

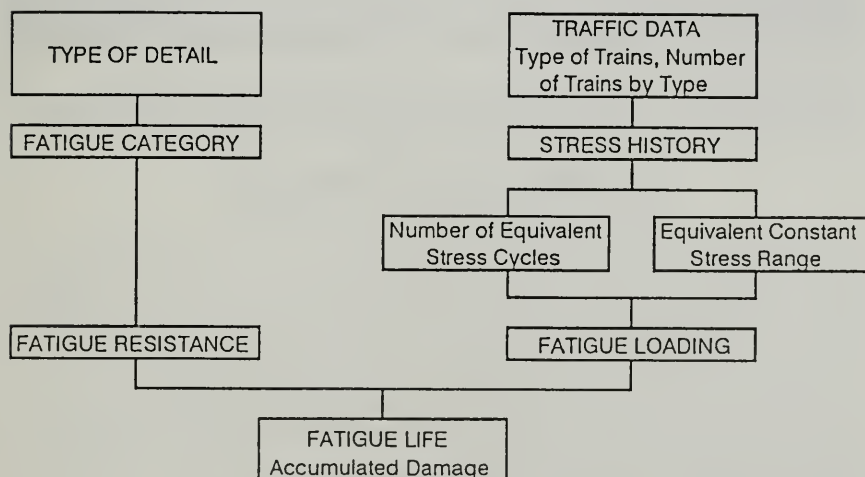


Figure 6. Flowchart for Fatigue Life Evaluation.

The main factors affecting the fatigue life of a detail are the fatigue resistance and the fatigue loading of that detail. The fatigue resistance is determined from the fatigue categories and the S_R - N relationships used in design. The fatigue loading of each train type is defined in terms of loading range and number of cycle values, as a function of the length of influence line of the member investigated. The fatigue loading data was computed from stress history plots using Miner's rule for the summation of damage and a rainflow cycle counting method [5] for breaking down complex stress cycles into equivalent numbers of constant amplitude cycles.

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3.2 Fatigue Loading Analysis

The analytical work involved in deriving the fatigue loading of each train type included the following steps:

1. Development of typical locomotive, freight car and freight train fatigue loadings,
2. Adjustment of typical freight train fatigue loading to stress values resulting from Cooper E-80 loading,
3. Determination of analytical relationships between adjusted number of cycles and lengths of influence lines.

3.2.1 Typical Locomotive, Freight Car and Train Fatigue Loadings

Load histories caused by the passage of typical locomotives, freight cars and trains were derived for various length of influence lines. They include fluctuations of moment, shear or reactions with time (see Figure 7).

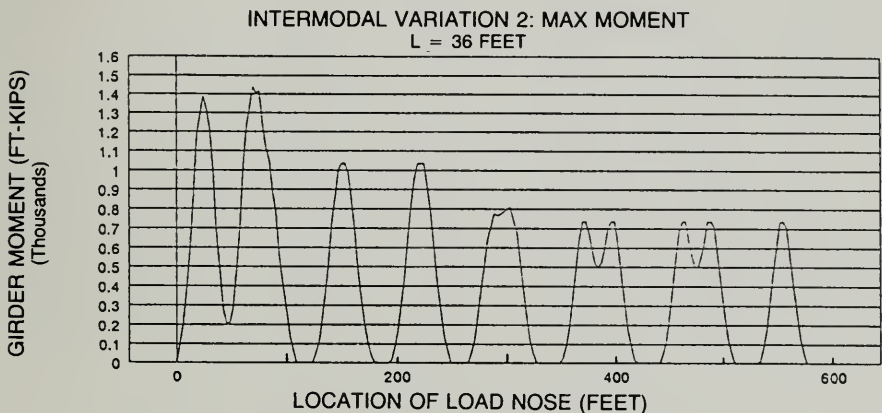


Figure 7. Example of Load History Used to Compute Fatigue Loadings.

From these load histories, fatigue loading data (see example in Table 5) could be computed for each train type.

The following typical locomotive combinations were analyzed:

- Cooper E-1 Loading—One Engine
- Cooper E-1 Loading—Two Engines
- Four 4-axle locomotives
- Six 4-axle locomotives
- Four 6-axle locomotives
- Six 6-axle locomotives
- Two 4-axle locomotives and two 6-axle locomotives
- Two 4-axle locomotives and three 6-axle locomotives

For each typical freight car (A, B, C, D, E, F and G) the car combinations investigated included:

- Two loaded cars
- Four loaded cars
- Ten loaded cars
- One loaded car followed by two empty cars followed by four loaded cars

No. of Cycles, Moments, Shears and Pier Reactions
(All values are per track)

LENGTH OF INFLUENCE LINE (Ft)	MAXIMUM MOMENT (Ft—Kips)	MAXIMUM END SHEAR (Kips)	MAXIMUM PIER REACTION (Kips)	NO. OF CYCLES
6	104.10	69.40	69.40	360.00
7	121.45	76.21	69.40	250.70
8	138.80	82.04	69.40	205.55
9	156.15	87.86	69.40	160.41
10	173.50	93.69	69.40	115.26
11	204.03	98.18	72.36	114.81
12	234.57	102.67	75.32	114.36
13	265.10	107.15	78.28	113.90
14	295.64	111.64	81.24	113.45
16	376.14	120.73	90.41	113.00
18	476.08	129.94	102.80	113.00
20	576.02	139.15	115.20	113.00
24	784.22	158.05	130.08	113.00
28	1000.34	172.62	142.28	113.00
32	1253.27	188.26	155.38	109.99
36	1552.57	205.31	170.87	98.92
40	1888.44	219.00	188.09	72.72
45	2309.94	236.89	204.84	49.99
50	2731.44	254.84	218.23	31.73
55	3152.94	269.52	229.19	22.90
60	3647.57	280.41	241.49	16.87
70	4636.84	302.19	266.10	4.82
80	5760.81	332.59	284.18	1.49
90	6884.79	363.00	302.27	1.05
100	8008.76	393.40	320.35	1.00
120	11675.70	456.18	376.86	1.00
140	15928.23	515.96	436.06	1.00
160	20180.75	575.74	495.27	1.00
180	25236.01	634.95	558.38	1.00
200	31094.01	690.52	621.88	1.00
250	47130.89	829.20	751.26	1.00
300	66955.99	963.79	892.75	1.00
350	90791.25	1080.32	1019.51	1.00
400	114626.50	1196.85	1146.27	1.00
500	171205.70	1393.69	1369.65	1.00

Table 5. Example of Fatigue Loading of a Unit Coal Train Type.

The fatigue loadings of the unit type and intermodal trains were derived directly from the load histories they generate. For the derivation of the mixed freight type trains fatigue loadings, combinations of locomotive and freight car fatigue loadings were used.

3.2.2 Adjustments to Cooper E-80 Loading

In order to reduce the fatigue loading data derived for each train type, the equivalent number of cycles computed for each length of influence line was adjusted to stress values caused by Cooper E-80 loading. The adjustment consisted of calculating the number of cycles per train, which, when used with stress ranges computed based on E-80 loading, would yield the same amount of damage. By using the Cooper E-80 loading adjustments, the fatigue loading of each train type could be expressed in terms of adjusted equivalent number of cycles only. This approach facilitated easy comparison between train types. Also, it simplifies the evaluation process, since Cooper E-80 is the standard loading used in design.

When the adjusted number of cycles are plotted against the influence line length on a log-log scale (see Figure 8), a few relatively straight line regions become apparent.

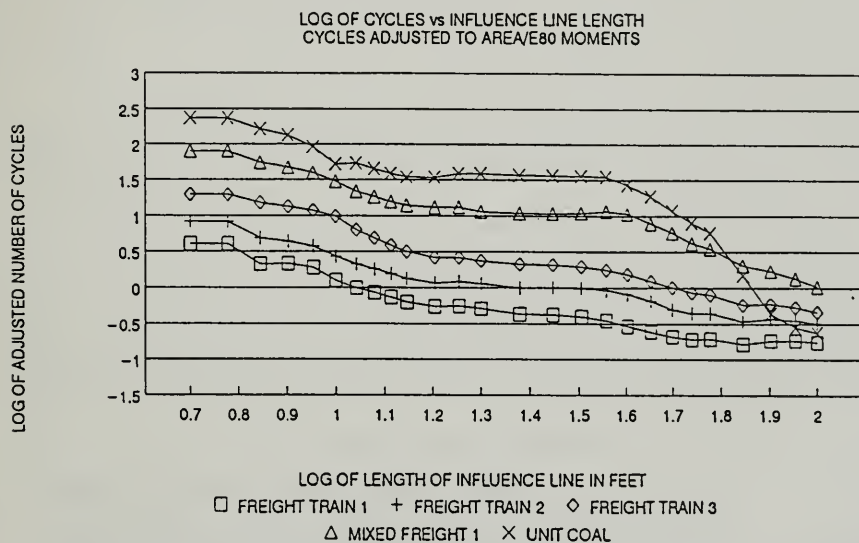


Figure 8. Adjusted Number of Cycles vs. Length of Influence Line.

3.2.3 Mathematical Model

The relationships between adjusted number of cycles and the length of influence line may be approximated as shown in Figure 9.

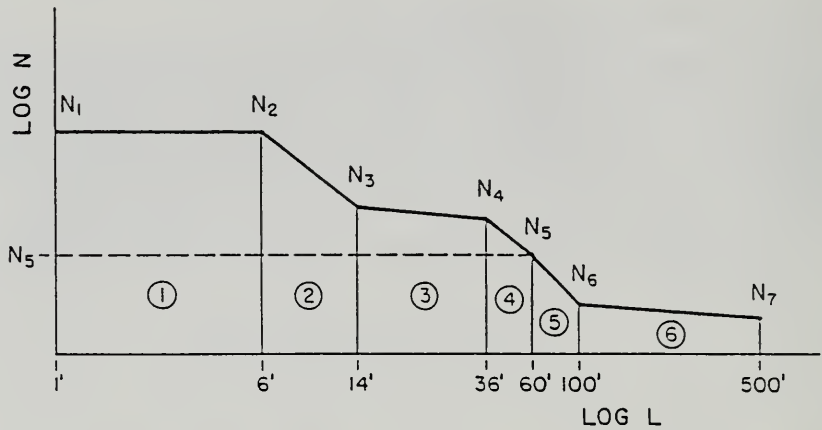


Figure 9. Approximation of the Relationship Between Adjusted Number of Cycles and Length of Influence Line.

This relationship may be expressed mathematically as follows:

$$\log N = \log N_1 - \left[\frac{\log N_1 - \log N_{I+1}}{\log L_{I+1} - \log L_1} \right] (\log L - \log L_1) \tag{1}$$

Values for the constants N_I for the typical trains used for Time Periods 1 through 4 are given in Table 6.

Train Type	L = 1.0 FT (1)	L = 6.0 FT (2)	L = 14.0 FT (3)	L = 36.0 FT (4)	L = 60.0 FT (5)	L = 100.0 FT (6)	L = 500.0 FT (7)
Freight Train 1	5.00	5.00	1.00	0.63	0.40	0.35	0.20
Freight Train 2	10.0	10.0	2.00	1.26	0.70	0.63	0.32
Freight Train 3	22.4	22.4	4.00	1.80	1.10	0.63	0.38
Freight Train 4	41.7	41.7	7.10	2.50	1.40	0.80	0.62
Passenger Train 1	0.54	0.54	0.14	0.13	0.13	0.08	0.002
Passenger Train 2	1.05	1.05	0.27	0.24	0.24	0.15	0.005
Passenger Train 3	1.82	1.82	0.48	0.43	0.43	0.27	0.008

Table 6. Constants N_I for Typical Trains for Time Periods 1 through 4.

For the typical trains used during Time Periods 5 and 6, for which detailed information could be collected, the N_I values were expressed in terms of local traffic data instead of being used as constants. The formula developed for N_I ($I = 1$ to 7) is given below:

$$N_I = N_{Ia} \left(\frac{P_I}{TC(I,1)} \right)^e + N_{ca} \left(\frac{P_c}{TC(I,2)} \right)^3 + \text{MAX} \left[\left(\frac{P_I}{TC(I,3)} \right)^3, \left(\frac{P_c}{TC(I,4)} \right)^3 \right] \quad (2)$$

where:

N_I	—	boundary values of equivalent cycles;
N_{Ia}	—	number of locomotive axles;
N_{ca}	—	number of car axles;
P_I	—	locomotive axles load;
P_c	—	car axle load;
$TC(I, J)$	—	train constants;
$I = 1$ to 7		
$J = 1$ to 4		

Train constants TC were computed for each of the train types considered. Using this formulation, train data specific to a given operating segment and direction of traffic as well as any future changes in the weight and number of locomotives and cars in a train can be taken into account.

3.3 Method of Assessment

A computerized method that uses the traffic data collected and the fatigue loadings developed was formulated. Incremental and accumulated fatigue damage values are produced.

The input data includes information on the bridge and the bridge member investigated, and data on railroad traffic. The bridge types considered consist of single track bridges on single track lines, single track bridges on double track lines and double track bridges. Incremental fatigue damage values are computed for each time period and train type. Values of cumulative damage to present and to a desired projection year are also calculated. A sample input and output showing cumulative damage values is

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illustrated in Figure 10. An output sheet containing incremental damage values is also produced. The fatigue damage is expressed in terms of ratios between number of cycles corresponding to an adjusted stress range and number of cycles for which that stress range would be allowed by an appropriate AREA S_R - N curve. The S_R - N curves are associated with a high (95%) confidence limit. Cumulative damage values larger than 1.0 are not indicative of the definite appearance of fatigue cracks but rather the disappearance of confidence that cracks due to primary stress cycles will not occur in the near future.

Using the fatigue damage values computed and the rate of fatigue damage per year the remaining safe fatigue life of a bridge can be estimated. Making changes in the projected future traffic data, effects of increased number of trains, car weights or number of loaded cars per train can be investigated.

BRIDGE AND TRAFFIC INPUT DATA:

BRIDGE: *BR. NO. 3.80, 202' TRUSS SPAN*
YR. ERECTED: *1902*
OPS NO: *272 PACIFIC JCT.-OREAPOLIS*
MEMBER: *INT. STRINGER, AT CENTERLINE*
INFLUENCE LINE LENGTH: *25.25 FT*
FATIGUE CATEGORY (A-E): *D*
FRACTURE CRITICAL (Y, N): *N*
DIRECTION (E,W,B,M): *B*
DESIGN STRESS RANGE: *6.45 KSI*
DESIGN IMPACT FACTORS
STEAM ENGINE: *75.40*
DIESEL, ELECTRIC: *55.50*
ACT/CALC STRESS RATIO: *0.90*
ACT/CALC IMPACT RATIO: *0.65*
OTHER RAILROADS: *0% OF BN TRAFFIC*

ACCUMULATED FATIGUE DAMAGE DATA:

PRESENT YEAR *1992*
ACCUMULATED FATIGUE DAMAGE TO 1992: *0.756*
PROJECTION YEAR: *2000*
ACCUMULATED FATIGUE DAMAGE TO 2000:
—BASED ON 1984-1989 TRAFFIC: *0.961*
—BASED ON 1990 TRAFFIC: *1.035*

FUTURE TRAFFIC DATA:

TRAIN TYPE	NO. OF TRAINS PER YEAR		NO. OF ENGINES PER TRAIN		NO. OF LOADED CARS PER TRAIN		AVG. WT.(TONS) OF LOADED CAR	
	FUTURE/PRESENT		FUTURE/PRESENT		FUTURE/PRESENT		FUTURE/PRESENT	
MIXED FREIGHT	<i>3357</i>	3039	<i>3</i>	3	<i>51</i>	51	<i>103</i>	99
UNIT COAL	<i>4585</i>	3530	<i>4</i>	3	<i>113</i>	111	<i>132</i>	130
UNIT GRAIN	<i>80</i>	69	<i>4</i>	4	<i>119</i>	119	<i>127</i>	127
UNIT POTASH	<i>0</i>	0	<i>5</i>	5	<i>100</i>	100	<i>131</i>	131
UNIT ORE	<i>0</i>	0	<i>0</i>	0	<i>0</i>	0	<i>0</i>	0
UNIT PELLET	<i>0</i>	0	<i>4</i>	4	<i>115</i>	115	<i>131</i>	131
LIGHT ENGINE	<i>2</i>	1	<i>27</i>	17	<i>0</i>	0	<i>0</i>	0
EXPEDITER	<i>321</i>	321	<i>1</i>	1	<i>15</i>	15	<i>82</i>	82
INTERMODAL	<i>377</i>	296	<i>3</i>	3	<i>84</i>	43	<i>86</i>	72
IML CONTRACT	<i>0</i>	0	<i>0</i>	0	<i>0</i>	0	<i>0</i>	0
GENERIC	<i>0</i>	0	<i>0</i>	0	<i>0</i>	0	<i>0</i>	0

Figure 10. Input/Output Sample of the Fatigue Damage Assessment Spreadsheet.

4.0 SUMMARY AND CONCLUSIONS

Historical traffic data was collected on the main lines of the Burlington Northern Railroad. A procedure that estimates the rate of fatigue damage per year and the remaining safe fatigue life of a bridge was developed. For Time Periods 1 through 4 (1900-1969), the procedure uses typical trains of constant composition per time period. For Time Periods 5 and 6, for which detailed traffic data exists, the procedure uses typical trains whose composition varies with the operating segment and the direction of

traffic. By using typical train fatigue loading that adjusts to changes in the composition of the train, effects of increased axles loads or of changes in the number of locomotives and loaded cars in a train can be investigated. The fatigue damage assessment procedure may be used as a tool to compare the condition of different bridges or of different members of the same bridge, plan bridge repairs and replacements, and to forecast long-range capital expenditures. It allows for calibrations in the future and for incorporation of site-specific data derived from field measurements.

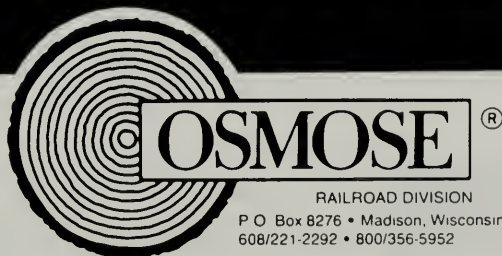
5.0 REFERENCES

1. Sweeney, R. A. P. (1976). "The Load Spectrum for the Fraser River Bridge at New Westminster, B.C.," *Proceedings AREA*, Vol. 77, Bulletin 658, 577-597.
2. Szeliski, Z. L. (1982). "Bridge Fatigue Studies," *Proceedings AREA*, Vol. 83, Bulletin 688, 522-531.
3. Szeliski, Z. L. (1984). "Fatigue Investigation of a Railroad Truss Bridge," *Canadian Journal of Civil Engineering*, Vol. 11.
4. Prucz, Z. and Conway, W. B. (1989). "Extending the Fatigue Life of the U.S. 190 Mississippi River Bridge, Baton Rouge, Louisiana," *Proceedings—6th Annual International Bridge Conference*, Pittsburgh, Pennsylvania, 308-316.
5. Bannantine, J. A., Comer, J. J. and Handrock, J. L. (1990). *Fundamentals of Metal Fatigue Analysis*, Prentice Hall, New Jersey.

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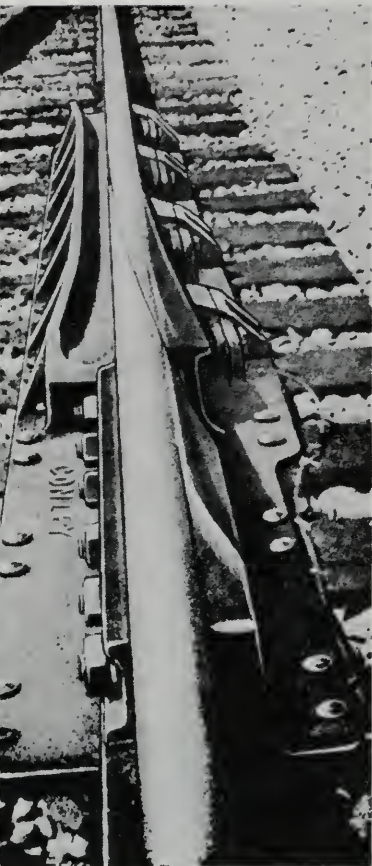
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BALLAST TESTING RESEARCH FOR QUARRIES SERVING SOUTHERN PACIFIC LINES

By: L. E. Meeker*, and D. H. Warnock**

Introduction

A railroad ballast of high quality is necessary to ensure long-term track stability and to control maintenance costs. Ballast costs for material and labor can be a substantial part of the budget allocated to maintain the rails, ties and ballast. There exists a definite need, therefore, to tie these costs to ballast quality and engineering performance. The demand for high-quality ballast will increase as traffic volumes, wheel loads, and train speeds increase in response to changing technologies.

Ballast maintenance costs are tied to material quality and quarry processing methods. The distance a ballast is hauled before use, and the traffic density for each rail line section, also will have a significant effect. Numerous groups, including the Association of American Railroads, the Canadian Pacific railroad, and the University of Massachusetts at Amherst, recently have conducted research on these ballast factors. This study extended the earlier work by completing an evaluation of all major ballast sources on the Southern Pacific Lines. It covered a wide geographic region and exhibited a high degree of depth and diversity.

This project had three major phases. The first was to evaluate both the geological features and the mining, processing, storing and loading operations at major ballast quarries that supply or could supply ballast to Southern Pacific Lines. These quarries, depicted in Figure 1, are located throughout the western and central United States. The second purpose was to analyze data from a comprehensive series of physical and chemical laboratory tests on ballast samples from those quarries. The third was to evaluate the annual maintenance costs of major sections of the rail system using an economic computer model. The authors then recommended specific methods that Southern Pacific may use to reduce maintenance costs. These methods included changes in quarry processing, adherence to a strict quality control program, the elimination of low-quality ballasts, and revised track maintenance procedures. The authors have included general recommendations based on the separate results of each project phase, and a summary section of specific recommendations.

Ballast Characteristics and Functions

Traditional materials used for ballast include a wide range of igneous, metamorphic and sedimentary rocks; also used are the industrial by-product slags from copper smelters and steel mills. Igneous rocks typically account for the greatest number of ballast types, and include granites and "traprocks" (traprocks are basalts, andesites, and other fine-grained dark igneous rocks). Metamorphic rock types used as ballast include quartzites and greenstones. Greenstones are altered basalts, and for this application the authors have grouped them with the igneous rocks. Carbonate sedimentary rocks used as ballast include dolomites and limestones; these, however, are losing popularity on most railroads in the United States. The materials tested in this study are depicted in Figure 2.

The primary functions of ballast are to (1) uniformly distribute loads to the underlying sub-ballast and subgrade; (2) provide lateral, longitudinal and vertical support for the track structure; (3) provide a medium that allows for easy adjustment of track geometry; and (4) facilitate track drainage.

To accomplish these functions an acceptable ballast must possess several desirable qualities. These include satisfactory ratings for strength, toughness and durability (resistance to abrasion and weathering), stability and angularity, drainability, cleanliness, availability, and economic cost.

The dynamic loading of rail traffic breaks individual ballast particles into smaller fragments, or abrades them and creates "fine" particles. The "fines" migrate downward and fill voids between other particles. As the voids fill, the ballast loses its ability to drain the track structure due to a decrease in permeability; it also loses much of its shear strength and elasticity. Such a condition will lead to a loss of

*Research Engineer, University of Nevada, Reno

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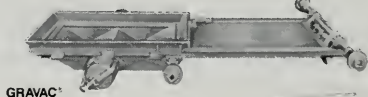
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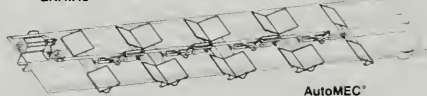
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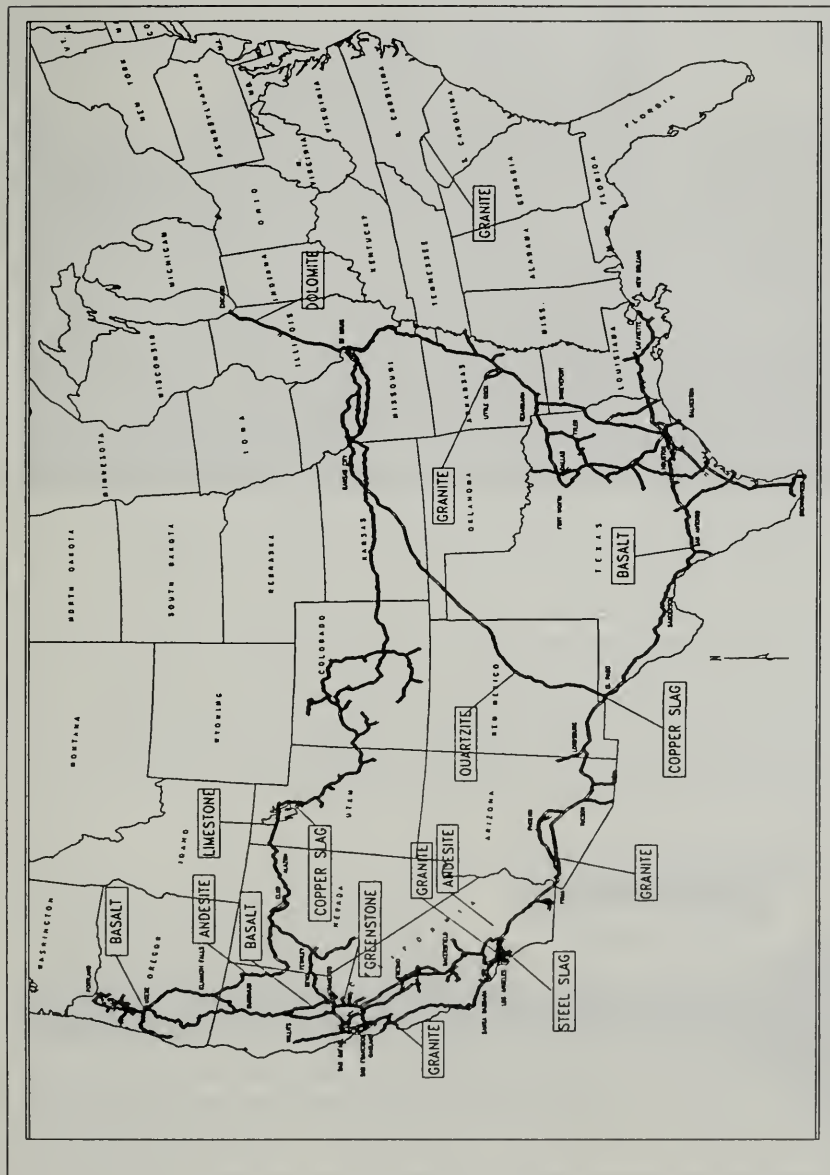
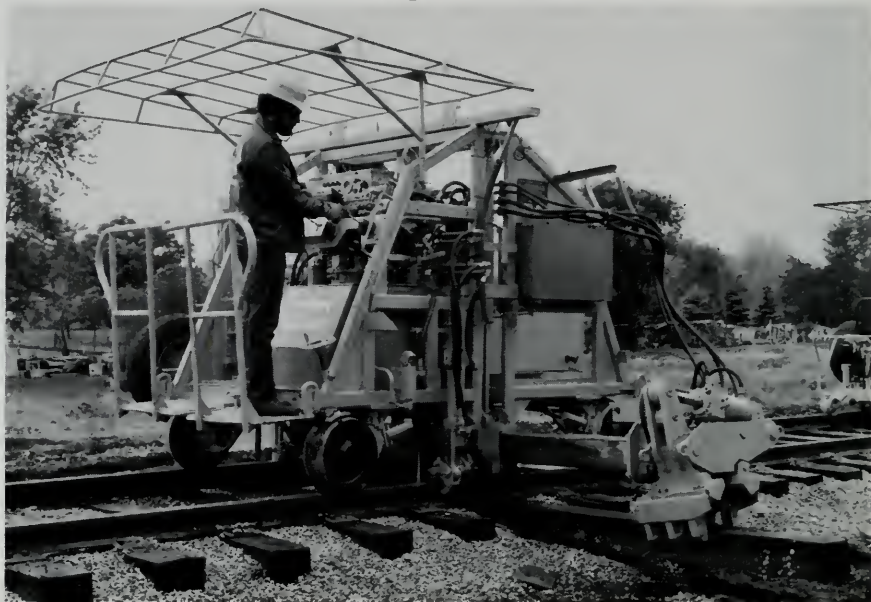


Figure 1. Locations of Southern Pacific Lines ballast suppliers and general areas served.

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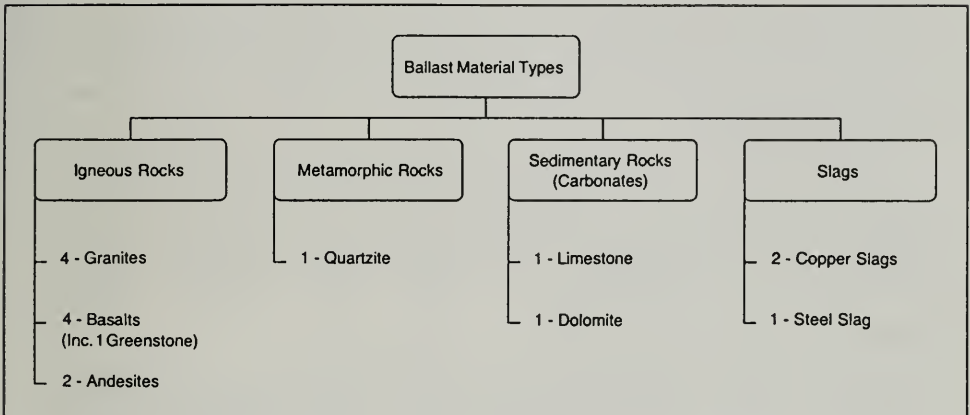


Figure 2. Ballast materials types represented in this study.

track geometry and a continued deterioration of track components over time. When the voids are filled and lose the capacity to hold more fines, the ballast is then "fouled" and has reached the end of its functional lifespan.

Traffic loading induces a zone of pressure on ballast that is most intense directly beneath the ties. This pressure begins to equalize at a depth of seven to nine inches. There should be a layer of clean, elastic ballast of that thickness to distribute tie loading to the subgrade without overstressing it. This layer is maintained by adding new ballast to offset the rate of fines accumulation, or by various means of ballast undercutting or cleaning.

Ballast Sources and Material Quality

Ballast from sixteen different quarries is included in this report. Between July 1989 and March 1990, a team of engineers from Southern Pacific Lines and the University of Nevada at Reno traveled to and evaluated fifteen ballast quarry operations. The quarries were located throughout the territory served by the railroad, and represent past, present and potential ballast sources for the railroad. The surveys included an inspection of the quarry face, to correlate observed rock strata to local geology, and to check for deleterious geologic elements; and an evaluation of ballast processing, storing, and loading operations.

The authors gathered approximately 180 pounds of sample material from the fifteen quarries for laboratory testing at the University. The operator at the sixteenth quarry supplied ballast samples and site information. A sample from North Carolina, for which extensive test data were available, was added as a benchmark to estimate the margin of error.

Ballast quality is affected by the characteristics and conditions of the parent material (quarry rock or slag), and by the occurrence of faults, fractures, or zones of altered minerals; many quarries will experience minor variations within the main rock body that will alter the material properties.

Other factors that affect quality include variations in the methods of mining, processing, storing and loading of the ballast products. Ballast stored on the ground in stockpiles may segregate or become dirty, particularly if stored in an area where surface water accumulates. To minimize this, quarry operators can load cars directly from conveyors, store material in overhead bins, or wash ballast over a wet screen immediately before loading.

Improving the quality of ballast may be the best way to reduce overall maintenance costs. There is a definite need to develop more rational methods to select ballast. In the past many ballast purchases were based on subjective judgments of ballast quality and geographical division lines, rather than on a rigorous set of quantitative test data for each ballast and an evaluation of annual maintenance costs based on ballast quality. Some low-quality ballasts are purchased at high relative costs due to double and triple handling, and to transportation distances.

There exists much variability among the quarry operations when comparing ballast quality, processing and storage procedures, production capacities, reserves, and available forms of transportation. The railroad should focus on those quarries with high-quality material, acceptable ballast handling procedures, capacity and supply sufficient to meet long-term demand, and with an economical hauling method to company rail lines.

Physical and Chemical Laboratory Tests

Laboratory tests measure material quality and thus may predict field performance. Tests that measure an aggregate's resistance to abrasion and breakage include mill abrasion, Los Angeles abrasion, and durability index. Tests that measure an aggregate's resistance to physical and chemical weathering include absorption and sodium sulfate soundness.

Tests that measure an aggregate's inherent characteristics include bulk specific gravity, unit weight, void content, and clay lumps & friable particles. Tests that measure post-processing (or modifiable) properties include flat and elongated particles, sieve analysis and percent passing the No. 200 sieve. The authors adhered to guidelines, where applicable, specified by the American Society for Testing and Materials (ASTM). The petrographic evaluation was the only qualitative test method used for material analysis. It determines an aggregate's mineralogy, gives an estimate of physical and chemical properties, and provides an appraisal of overall expected durabilities. The authors followed petrographic guidelines designed for previous studies.¹

For the Los Angeles abrasion test, the authors used grading No. 3 (ASTM 535-coarse aggregate). This grading is most representative of the ballast size in use on Southern Pacific lines. It is only through the consistent use of the same grading that these test results are comparable from one sample to another.

At the time of this study, Southern Pacific had not adopted the grading envelopes recommended by the American Railway Engineering Association (AREA). Sieve analysis results varied widely, and generally yielded minus 3/4" fines in excess of that allowed by AREA gradings No. 3 and No. 4. Most of the samples came from loaded ballast cars, rail side stockpiles, or from conveyor lines loading rail cars. These samples were all subject to the maximum amount of segregation that occurs from successive handling operations and are most representative of the grading the railroad actually receives for use as ballast.

The mill abrasion test measures a material's effective hardness or its resistance to abrasion. It is a wet abrasion test, simulating failure from particle grinding in the presence of water, that removes ballast of a specific grading together with water in a ceramic jar. The test is relatively new and is currently under review for consideration of inclusion in ASTM and AREA guidelines.

Standards combine the results of several tests and may be useful for judging simultaneously numerous material properties. The Los Angeles abrasion test primarily produces fractured particles larger than the No. 200 sieve, whereas the mill abrasion test primarily produces fines smaller than that size. The abrasion number provides a measure of quality (lower number = better quality):

$$\begin{aligned}\text{abrasion number} &= \text{Los Angeles abrasion value} \\ &+ 5 \times \text{mill abrasion value}\end{aligned}$$

The California Department of Transportation found that some tests favor certain rock groups and discriminate against others.² It accordingly has developed a standard, the durability absorption ratio, that

allows for use of a material weak in one property but strong in another. The ratio is an empirical number from 0 to 100 (100 = best) that estimates the quality of an aggregate:

$$\text{durability absorption ratio} = \frac{\text{durability index}}{(\% \text{ absorption} + 1)}$$

The California agency personnel found that the durability absorption ratio values correlated well with visible evaluations of exposed aggregate performance 97% of the time.

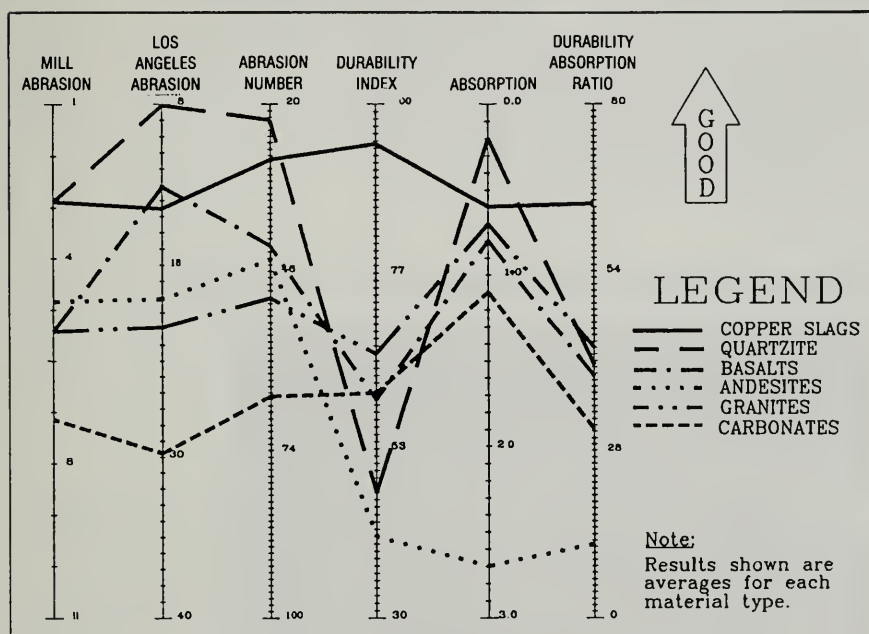


Figure 3. Ballast laboratory tests.

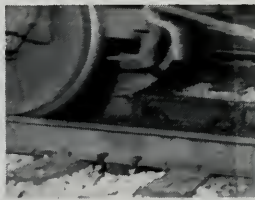
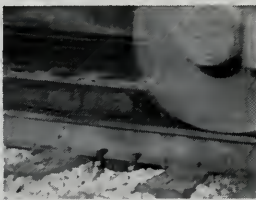
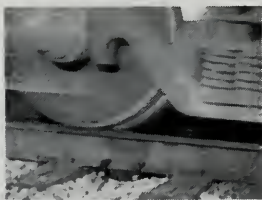
The test results and standards are depicted in graphical form, according to rock group, in Figures 3 and 4. The steel mill slag (which performed poorly in the tests, and no longer is considered a viable ballast source) and the North Carolina ballast (the benchmark sample; a granite) are not included in the graphs. The results of the sieve analysis also are not depicted.

Each test is intended to depict a particular aspect of predicted ballast quality and function. As certain tests may discriminate against one rock group and favor another, it may not be feasible to require all quarry operators to meet the same governing specifications for ballast material quality and other parameters.

A complete petrographic evaluation for the sixteen samples is outlined in a separate report.³ Petrographic analysis is the evaluation of ballast samples using hand samples and microscopic thin sections to determine aggregate type, mineralogy, texture, structure, mechanical and chemical properties, and properties of degraded fines. The analysis also ascertains whether fractures or cemented fractures, a source of potential weakness, exist in the ballast source.

Based on the results of the petrographic evaluation, the authors divided the samples into groups predicted to display low, moderate, or high durability as ballast. One can use the qualitative petrographic

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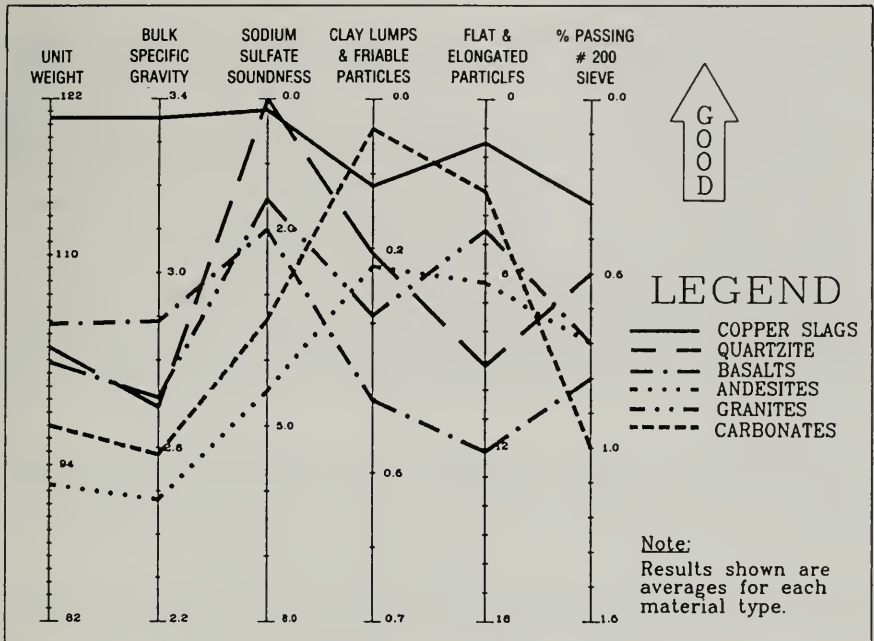


Figure 4. Ballast laboratory tests.

examination to check the quantitative results of the other laboratory tests. It is very important that the petrographic samples, especially the microscopic thin sections, be representative of the quarry rocks. In most cases, the petrographic evaluation results agreed well with the balance of the laboratory test results.

The authors placed most emphasis on the abrasion number and durability absorption ratio values, and on the results of the petrographic study. When combined, these values and results define the most important parameters of ballast quality. These include resistance to abrasion, the potential to generate clay-like fines, susceptibility to freeze-thaw cycles, mineralogy, structure, and mechanical/chemical properties. Engineers then can use this information to estimate the expected durability of each ballast aggregate in use or considered for use.

Railroads can obtain ballast of high quality only if they improve material specifications governing physical and chemical aggregate properties. A joint cooperation between railroads and quarries is necessary to effectively implement quality control practices necessary to ensure compliance.

Economics of Ballast Maintenance

The average annual cost per mile of track for ballast renewal and maintenance is not uniform for each track section. It varies according to the ballast unit cost and quality, transportation method and distance hauled, annual tonnage and other factors. One method to evaluate where it may be possible to reduce expenses is to determine the annual cost for each track section of interest.

The Association of American Railroads (AAR) has developed a computer program that estimates the annual cost and ballast life for any given segment of rail line. The Ballast Renewal Model evaluates the results of differing the ballast parameters of cost per unit volume, quantity per mile of track, haul distance and gradient, material quality and grading, annual train tonnage and maintenance cycles.⁴

Railroads generally purchase ballast by the ton; the price reflects processed ballast loaded into rail cars. The sixteen primary ballast quarries surveyed in this study charge between \$4.00 and \$7.00, with an

average price of \$5.25. The unit cost is heavily dependent upon the type (truck or rail) and distance of haul from the quarry to Southern Pacific rail cars (which can add up to an additional 50% to the purchase price), but not necessarily on the material quality.

The annual maintenance cost of a track section increases exponentially with increases in traffic because the latter induces more frequent maintenance intervals; this increase will be especially pronounced on track sections with low-quality ballast (high abrasion number values). This clearly outlines the need for using only high-quality ballasts on rail lines with high traffic levels. The Model's evaluation of ballast quality, however, is limited to the abrasion number and does not consider the results of the other physical and chemical tests.

The economic evaluations generated by the Model are based on AAR studies that attempt to generalize the maintenance procedures actually used by domestic railroads, and represent ideal planning and cost scenarios. In actuality, the undercutting and maintenance procedures outlined in the Model are not in place on Southern Pacific lines, and may not be in place on other major railroads in the United States.

This Southern Pacific study does offer a foundation, however, for future research projects because railroads can fine-tune the program to meet their specific needs and procedures. Its correlation to potential savings for Southern Pacific, when compared to actual maintenance procedures, will remain theoretical and represent an idealized maintenance scenario. The adoption of renewal or undercutting procedures is necessary to achieve the maximum projected economic return.

The project used the Model to evaluate the annual cost of approximately 60% of the Southern Pacific system, encompassing 135 rail sections (line segments) with a cumulative total of 8700 track miles. It included all sections that in 1989 had traffic levels over one million gross tons.

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This study calculated theoretical annual cost values for each operating division of the railroad, using both ballast then-in-use and other ballasts considered as replacements for low quality materials. Current practice usually terminates ballast shipping at operating division boundaries, especially if train crews change at those locations. In many cases it was possible to reduce the costs per mile by substituting an adjacent source of higher quality ballast, even if the replacement material cost more per ton and was hauled a longer distance.

An example of this process is depicted in Figure 5. The 528-mile track section is bounded by a low-quality granite quarry on the west end and a high-quality quartzite quarry on the east end. Currently the track is ballasted with the granite ballast that costs \$5.75 per ton. By replacing the granite with the quartzite, available at \$6.60 per ton, the railroad theoretically can reduce maintenance costs over a range from 43% to 89% of current expenses. As the quartzite is hauled farther west, the projected savings decrease until eventually it reaches the limit of economic haul when the annual cost equals or exceeds current costs (at a location west of the sections depicted in the figure). There is an effective limit to the economic haul distance even for ballast of the highest quality.

Cost Comparison By Track Section

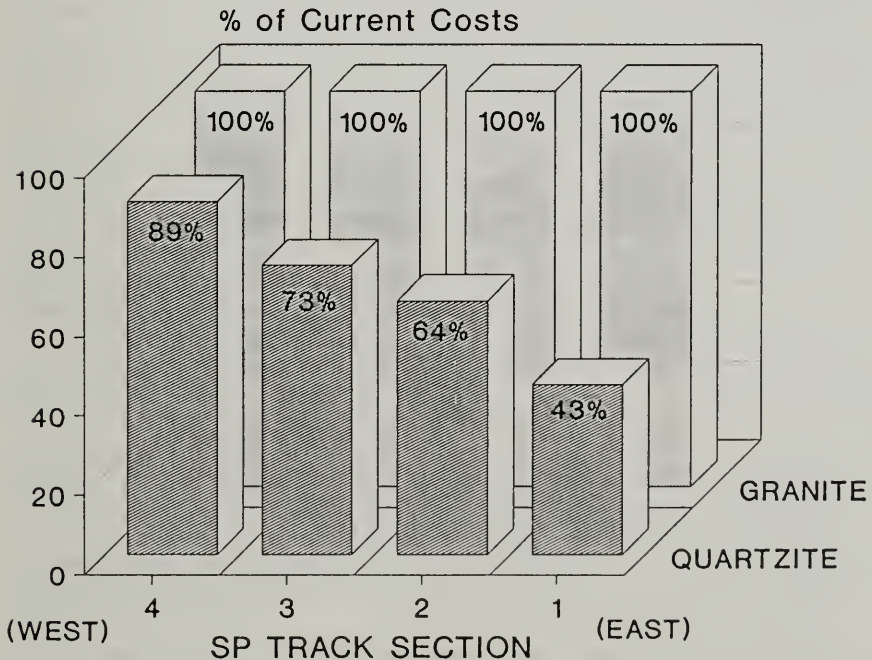


Figure 5. Cost comparison by track section.

Summary and Recommendations

A railroad that desires to improve its ballast purchase and use practices, should perform a comprehensive study of existing and potential ballast sources. The study should include quarry geology and ballast processing, a thorough series of laboratory tests, and a comparison of annual maintenance costs for track sections with high traffic levels. A study of these parameters is important when evaluating whether the use of a particular ballast resource is, or would be, economically justifiable. The following recommendations aim to promote the development of high quality ballast sources, to reduce material abrasion, fouling and segregation; to suggest guidelines for testing and quality control; and to reduce annual maintenance costs by extending ballast life. These recommendations are applicable not only to Southern Pacific Lines and its corresponding quarries, but also to other railroads and quarries nationwide.

- Minimize handling to reduce ballast abrasion, segregation and unit cost.
- Load ballast cars directly from conveyor belts or overhead tipples, or store ballast in well-drained, elevated locations adjacent to track side.
- Wash ballast over a screen just prior to loading rail cars, where water is available economically.
- Emphasize production at quarries with extensive high-quality ballast reserves.
- Establish a comprehensive quality control program for ballast. Adopt as a minimum the AREA-recommended guidelines. Revise ballast specifications for grading, and adopt as a standard AREA grading No. 3 or No. 4. Consider adopting tests for mill abrasion, durability index, and petrographic analysis; as well as the abrasion number and durability absorption ratio standards.
- Require new or potential ballast suppliers to perform a battery of qualification tests. Include, as a minimum, tests to measure abrasion and breakage, resistance to weathering, specific gravity and petrographic features.
- Perform all AREA recommended tests for existing ballast sources on a regular basis. Include also mill abrasion and durability index.
- Eliminate or reduce use of low-quality ballasts, especially on lines with annual traffic levels above 10 million gross tons.
- Consider the adoption of maintenance procedures that incorporate, in addition to surfacing, ballast undercutting or renewal operations. Since the zone of load-induced pressure is most intense directly beneath the ties, it is critical to place a layer of clean, unfouled ballast in that location.

References Cited

1. Raymond, G. P., 1985, Higher Standards for Track Ballast: Progressive Railroading, April 1985, pp. 51-54.
Watters, B. R., Klassen, M. J., and Clifton, A. W., 1987, "The Evaluation of Ballast Materials Using Petrographic Criteria," presented to Session on Performance of Aggregates in Railroads: Transportation Research Board, Washington, DC, 51 p.
2. Smith, T., McCauley, M. L., and Mearns, R. W., 1970, "Evaluation of Rock Slope Protection and Material," presented at the 49th annual meeting of the Highway Research Board: California Department of Public Works, Sacramento, CA, 13 p.
3. Meeker, L. E., 1990, "Engineering and Economic Factors Affecting the Cost of Railroad Ballast," a Master's degree thesis: University of Nevada, Reno, NV, 272 p.
4. Chrismer, S. M., 1989, Ballast Renewal Model User's Manual. Report No. R-701: AAR Technical Center, Chicago, IL, 40 p.

TEXAS HIGH SPEED RAIL PROJECT

Public/Private Financing for High-Speed Rail Transportation and the Texas Experience

By: Bob Neely*

Introduction

I want to spend my time sharing our perspective on high-speed rail finance. And, to explain the reasons why Texas has implemented high-speed rail without state funding, why that might not work everywhere, and why certain needed actions in Washington are crucial to high-speed rail in every state.

Requirements of Our Act

Primarily, interest in high-speed rail in Texas centered around transportation and economic enhancement. We wanted a better way to get to, from and among our major cities, and we wanted a chance to bring new industry to our state to diversify our economy.

One major provision has remained constant in Texas since high-speed rail was first discussed. No one at the state level has *ever* expressed strong interest in spending *state funds* on high-speed rail. Pressure from other politically powerful opponents has ensured that public assistance would be a non-option.

One section of our enabling legislation, in the preamble, states that "it is not in the public interest that a high-speed rail facility be built, financed, or operated by the public sector." However, another section of the act states that the Board may "accept donations, contributions, grants, or gifts from any source for any purpose, however, legislative appropriations or other state funds may be used only for planning but not for financing, acquisition, construction, maintenance, or operation of the high-speed rail facility."

The Senate sponsor of the act testified during our franchise application hearings that local and federal assistance was fine, but that the state was not going to spend any money. Southwest Airlines, which has attempted to derail our project through court action on two different occasions, has consistently argued that the act prohibits all public funds, direct or indirect, which our attorney believes, is selective reading of the act at best.

Our Board has maintained that public funds should not be a pre-condition for any financing plans of any franchise applicant, but that implementation of high-speed rail in Texas could benefit from federal or local funds. Possible examples include demonstration funds or grants, and the ability to cooperate with local transit authorities on mutually beneficial rail applications.

Promises/Commitments Made by Franchise Applicants

The Board issued a request for proposal in September 1990 asking anyone who wanted to apply for a franchise for certain information. The RFP didn't ask for interested parties to build a train from Houston to Dallas to San Antonio. Instead, it asked applicants the following:

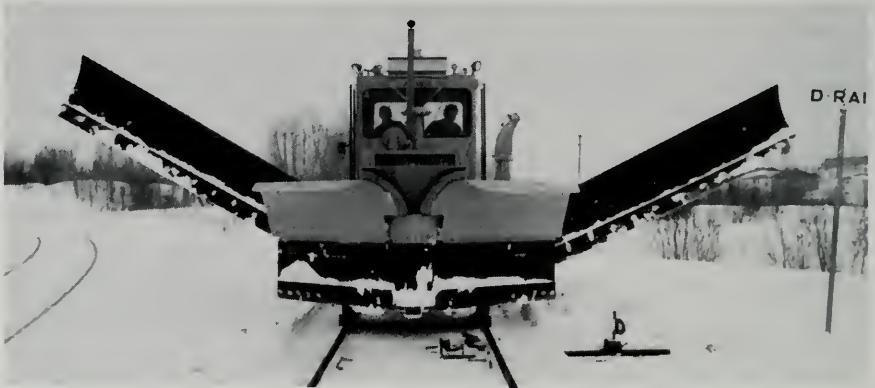
- Where are you going to offer service?
- What kind of service will it be?
- Where is the line likely to go?
- What kinds of equipment will you use?
- How many people do you think will ride it?
- How will it affect the environment?
- How much will it cost? and
- How will you pay for it?

Two consortia submitted applications for a high-speed rail franchise in January, 1990. Each application offered service to the same terminal cities, but got there different ways, and offered different start-up times for service. One application, Texas TGV, was based on French TGV-Atlantique technology. The other application, from Texas FasTrac, was based on German ICE high-speed technology.

*Executive Director, Texas High-Speed Rail Authority



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One fundamental difference in the two applications concerned their financial plans. Texas FasTrac based its plan on bond financing, including tax-exempt bonds, junior lien bonds and mortgage backed bonds. Texas TGV, on the other hand, proposed a mixture of tax exempt bonds and equity instruments.

In the final analysis, the Board adopted a hearing examiner's report that Texas FasTrac's financing plan did not meet the Authority's standards of being self-evidently self-sufficient without the use of public funds. Texas FasTrac depended on some level of public assistance, and did not have fully private financing. Texas TGV's financing plan was more complete, but that feature made it subject to strident attacks not only from Texas FasTrac but from Southwest Airlines as well. Incidentally, I should point out that Southwest Airlines participated in our application hearing process as an intervener party.

Texas FasTrac believed it was being penalized for being realistic. They and Southwest Airlines spent much time and money trying to prove that Texas TGV would never live up to its promises to make the project work without state funds. One major element of the franchise award decision favored Texas TGV's financing plan because it met the terms of our statute.

Financing Concerns During the Franchise Negotiations

For the past several months, we have been working diligently with the franchisee to reach terms of a detailed franchise agreement, the governing document which would state the obligations of both parties in implementing the project. In large part, this implementation process was based on certain findings made in the award of the franchise itself, which in turn was based on evidence presented during the hearings.

As part of this franchise agreement negotiation process, we noted that the franchisee sought maximum flexibility for project implementation, with respect to deadlines (see Appendix) and to the degree to which it remained wed to statements made during the application hearing process. We understood the franchisee's need for flexibility: in the real world, things change. As we've heard the franchisee explain, "We've all gotten smarter about what this project will actually entail." As the franchisee attempts to seek private funds for the project, certain features of the financial package submitted in the application may be outdated or unrealistic.

We also noted that additional caution about deadlines and milestone commitments was becoming more distant than articulated during the competition process. The franchisee and Authority have been very deliberate about protecting their positions in discussing a fifty year franchise agreement; much more so than they were in reaching consensus on the terms by which the franchise itself was awarded.

Given this caution and new respect for financial realities, during the franchise agreement negotiations, we discovered elements in the financing plans originally submitted which no longer reflected the current franchisee plans. Our challenge was how to respond to those changes. We had an obligation to hold the franchisee to promises which were made to secure the franchise award. Yet, we did not intend to be so inflexible as to prevent the franchisee from raising the money it would need in a manner it deemed most advantageous.

Our position, then, was to be reluctant to bend on the financial deadlines in the franchise award itself, and in the major assumptions and features of the financing plan presented during the many days of application hearings. However, we believed, and continue to believe, that our Board will be cooperative in allowing some leeway on the financing in the future, within certain boundaries, in order to get the project moving forward.

An important, indeed, historical milestone was reached on Wednesday, January 22, 1992, when the Board of Directors of the Authority adopted a final franchise agreement with the Texas High Speed Rail Corporation, the successor group to the Texas TGV Consortium. This franchise agreement spelled out many specific financial milestones which the Authority expects to be met if the franchise is to remain valid. There are many specific details to this document, but I would bring up the two major financial milestones for this current year. Within 10 days of the execution of the franchise agreement, the

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Corporation was required to capitalize itself with \$10 million, and maintain a net worth of \$3 million over the next year. This deadline was met. By December 31, 1992, the Corporation must secure equity financing commitments totaling \$170 million, including \$30 million in cash. By the end of this year, we will know the ultimate status of the project. It now remains for the franchisee to sell this project to the private capital markets. I will tell you they are working extremely hard on this milestone. We are optimistic they will succeed.

Future Legislative Efforts

Texas has been looked to as a model for high-speed rail implementation given our progress thus far. However, I must caution against too much reliance on replication of our process or philosophy. Primarily, I speak of Texas' prohibition against the use of state appropriated funds for the project. Study after study released in Washington states that high-speed rail will be impossible to implement successfully without some form of public assistance.

Let me put this succinctly: each state is completely free to determine its own position on public assistance for high-speed rail. Texas has a prohibition against state appropriated funds for high-speed rail because that was the 71st Legislature's choice. This does not mean that indirect state assistance in the form of revenue bonding authority for tax-exempt debt might not be possible in the future. Nor does this mean that every state must, in order to duplicate Texas' success, swear an oath against public funding for high-speed rail.

I realize that such tolerance must come as a surprise coming from a Texan, given our usual ease in telling everyone within earshot of "How we do things right in Texas." However, each state must be free to discover the appropriate form and level of state assistance for high-speed rail. The need for public assistance will depend on market forces more than anything else.

The high-speed rail assistance portions of the recently enacted Intermodal Surface Transportation Efficiency Act of 1991, referring to a high-speed rail demonstration project, actually penalizes states which have made a choice to limit state assistance. The new law specifies that the \$50 million demonstration project program funds cannot be spent in states where non-federal funds are prohibited for high-speed rail. This statement is currently being reviewed by various state and Federal staffs to determine the exact meaning.

So, am I saying that each state is on its own when it comes to determining levels of appropriate state funding roles? No. The recipe is simple: if a project serves a lucrative market with a proven technology, you might not need significant state funding assistance. However, once you alter either assumption; that is, if you consider a corridor without sustainable ridership or plan for a technology without proven capital costs and maintenance and operating figures, you may need to step in with state funding to attract private investment to your project.

State funding is not the only issue to consider in bringing high-speed rail to our region. All Americans interested in this mode of transportation must work to correct a glaring inequity in the federal tax code which limits the amount of tax-exempt debt available for high-speed rail projects.

The 1986 tax reforms placed a tight lid on the amount of economic development-related tax exempt bonds being floated by state and local governments across the country. For many reasons, these controls were needed and appropriate. However, they have placed arbitrary ceilings on the amount of tax-exempt debt available for important infrastructure projects like high-speed rail.

In 1988, these controls were lifted somewhat for high-speed rail. Each state has a certain amount of private activity debt it can issue in a given year. The 1988 changes in the law would count only 25% of a given high-speed rail bond issue against a state's private activity cap. This helped of course, but high-speed rail in any form or technology is so expensive that even 25% of these issues would crowd out many other worthwhile bond issuers. Of course, airport and port authority debt is exempt since these facilities serve more than one state, or so the argument goes.



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Although there were reasons for these private activity controls, those reasons do not necessarily apply to high-speed rail. Why?

First, *high-speed rail benefits a broad area*. Many tax-exempt bonds supported private development and expansion which had limited impact on the state's overall economy. High-speed rail in Texas will unite three of the largest cities in the U.S. and five of the largest cities in Texas, comprising over two-thirds of the state's total population.

Second, *high-speed rail creates jobs*. Many states use their tax-exempt bonds to lure jobs from one state to another. High-speed rail is completely new; it creates economic opportunity, not merely moves it from one place to another.

Finally, *the private activity cap forces states into unreasonable choices*. If high-speed rail debt is to be issued, it could only be done at the expense of other valuable public purposes now considered as "private activity," such as public housing mortgage bonds and college student loan fund bonds. Once a state has made the commitment to proceed with high-speed rail, they shouldn't have to decide whether high-speed rail is more important than affordable housing or higher education.

Conclusion

I normally end my remarks by asking people to consider writing their congressional delegation and urge them to support legislation to cure this problem. Specifically, Congressman William Coyne's H.R. 3488, filed last fall, would lift this artificial barrier against high-speed rail. The interest in Congress has grown significantly in recent years. It continues to grow. The more we can nurture this growth, the better for our transportation future.

Indirect federal assistance in this manner is completely appropriate. Our history is replete with examples of federal assistance on major infrastructure programs—many of them of a transportation nature (interstate highways, dams, bridges, tunnels, and even railways). Now, we have a chance to create a completely new *alternative* mode of transportation for our nation, and create new economic opportunities in the process. Let's all work together, not to salvage the glories of the past, but to forge the dreams of the future. I firmly believe we can make high-speed ground passenger transportation a reality for this, and future generations of Americans. Thank you.

Appendix

(Schedule of Deadlines as Mandated by the Franchise Agreement)

1. Execution of Franchise Agreement	January 31, 1992
2. Payment of THSRA Budget	February 7, 1992
3. THSRC \$10 Million Capitalization	February 7, 1992
4. Posting of \$2.5 Million Abandonment Bond	February 14, 1992
5. Submission of Communication Plan	March 16, 1992
6. Submission of Procurement Plan	April 1, 1992
7. Initiation of EIS	April 1, 1992
8. Initiation of Independent Ridership Study	April 1, 1992
9. Submission of Baseline Implementation Plan	November 25, 1992
10. \$170 Million Worth of Equity Commitments (\$30 Million Actually Invested)	December 31, 1992
11. Additional \$30 Million Equity Invested	June 30, 1993
12. Total Debt and Equity Commitments Obtained	December 31, 1994
13. Construction Commenced	May 27, 1997
14. Houston/Dallas-Fort Worth Service Commenced	December 31, 1998
15. San Antonio/Dallas-Fort Worth Service Commenced	December 31, 1999

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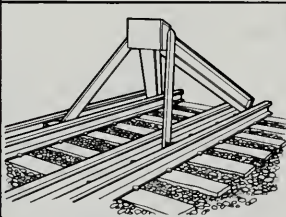
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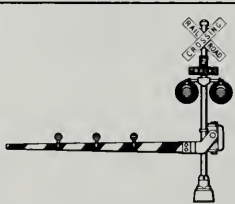


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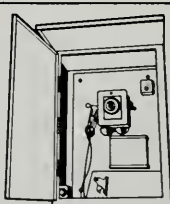
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STUDY OF UNCASSED PIPELINE CROSSINGS

By: J. B. Miller* and R. J. Boileau**

Good morning. I am sure that most of you are asking, "why should we as railroad engineers study uncased pipeline crossings?" I am also sure that those of you involved with the handling of crossing applications have noticed that the pipeline companies have been making more and more requests for uncased crossings which do not meet the specifications of most railroads or the recommendations of the AREA Manual (Chapter 1, Part 5). I know that the requests for uncased crossings will continue to increase. There are two primary reasons for this, first, the pipeline companies claim that they have no reliable way to monitor cathodic protection of a carrier pipe within a casing pipe and of course an uncased crossing is more economical. There have been pipeline accidents caused by corrosion failure of the carrier pipe within the casing pipe. This can and has been catastrophic in some cases. In one such accident that involved a highway crossing, the gas ignited causing an explosion and fire with both carrier and casing pipe coming up through the highway pavement. These are some of the reasons why we should be studying uncased pipeline crossings.

A 1986 survey by the Interstate Natural Gas Association of America found that there are 14,450 cased and 95 uncased crossings under railroads by transmission pipelines. These are just gas transmission lines so the total number of pipelines of all types under our railroads number many thousands, and unfortunately many are quite old. We will no doubt be seeing many applications for renewals and the pipeline companies will want to go with uncased carrier pipes. I have already seen some of this and I am sure many of you have seen such requests. All of us in the railroad industry have looked at pipelines as a nuisance and at times as a competitor. Well, times have changed. They are not going to go away and we as railroad engineers must continue to work with the pipeline engineers for the safety and best interest of the railroads, pipelines and general public. In fact, many railroads get their diesel fuel through direct pipeline delivery and some of our parent companies own pipelines.

Pipeline companies, like railroads, have made many technical improvements to their facilities to make their operations safer and more efficient. They, like the railroads, have supported and continue to support many research projects to produce improvements. One such project by the Gas Research Institute (GRI) specifically addressed the issue of cased/uncased crossings under railroads and highways. I would like to talk about this project this morning as it will most likely have a bearing on future crossings and the replacement of existing crossings.

The Gas Research Institute is the research arm of the gas industry similar to the Research section of the AAR. Back in 1985 the product transport section of GRI was requested to perform research concerning the crossing of railroads and highways by gas transmission and distribution pipelines, with the goal of developing a methodology to analyze the potential stresses in uncased and cased pipelines at the crossings, and select the most appropriate means of crossing a given site. The School of Civil and Environmental Engineering at Cornell University was awarded the contract to perform the research and develop a design methodology and design guidelines. At the beginning of the project Cornell/GRI set up an advisory committee composed of representatives of the gas pipeline industry, the railroad industry and the appropriate highway agencies. The AREA was contacted for the railroad representatives. Several major railroads and the AREA were represented at most all advisors' committee meetings at Cornell from 1986 through 1991. I had the pleasure of serving on the committee while working for the Santa Fe and have been representing the AREA on the project since I retired in 1990. Needless to say, I have learned a lot about pipelines. The project will probably be complete this year, the Guidelines and design methodology are complete for all practical purposes. I would like to give you an overview of the project with a few comments after which, Bob Boileau, Chairman of Subcommittee 5 will give us a review of Subcommittee 5 assignments and their status. Assignment D5-3-91, develop specifications for uncased high pressure gas pipelines within the railway right of way, should generate a great deal of interest!

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While the project covers railroads and highways I will confine my remarks to crossings under railroads. The project began with an extensive review of the present practice for design and installation of crossings in the USA, Canada, and several major foreign countries. It is interesting to note that the only governmental agency that requires encased crossings is the state of New York which adopted the AREA Manual as their regulation for lines under railroads. While most all state highway agencies do provide for encased crossings, most also have uncased alternatives. With the exception of the AREA, none of the professional organizations such as the ASCE, ASME and API require encased crossings, but they do provide design practices for encased crossings, and the Code of Federal Regulations governing pipelines does not require encased crossings. So we in the railroad industry along with some highway agencies stand alone in the requirement of encased crossings.

The research continued at Cornell with the development of three-dimensional finite element computer models of typical crossings to determine the stresses involved. It is interesting to note that present design practices for carrier pipe do not provide for external live load longitudinal bending stresses, only transverse flexure or circumferential live load stresses. Therefore, it was necessary to come up with a design methodology to provide for external live load bending stresses along with the usual dead load and internal live load stresses. This also requires the consideration of impact and other factors. The computer modeling done by Cornell was very helpful in the development of the design methodology for crossings, in that it helped identify all of the various stresses on the carrier pipe in an uncased or encased environment. The model will consider all necessary factors, such as pipe diameter, wall thickness, depth of burial, live loads (E 80 for railroads), impact, dead or earth loads, and site soil conditions. The results of many finite element analyses have been boiled down to straightforward design charts, and have been put forward in the Cornell/GRI design guidelines. Predictions made with the model were compared to present design practices which utilize the Barlow and Spangler formulas, which do not provide for calculation of longitudinal bending stresses. Both the circumferential and longitudinal bending stresses predicted using the new methodology were significantly less than those calculated by the old formulas. The model indicated that design of a crossing with an uncased carrier pipe could accommodate the E 80 live loads well within the specified minimum yield strength of pipe steel by adjusting the depth of burial and/or wall thickness.



Uncased pipeline installation under FAST Heavy Tonnage Loop at TTC, Pueblo, CO.

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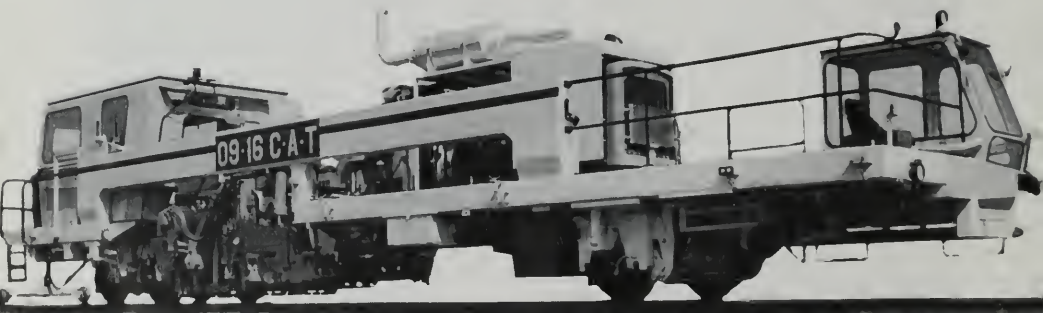


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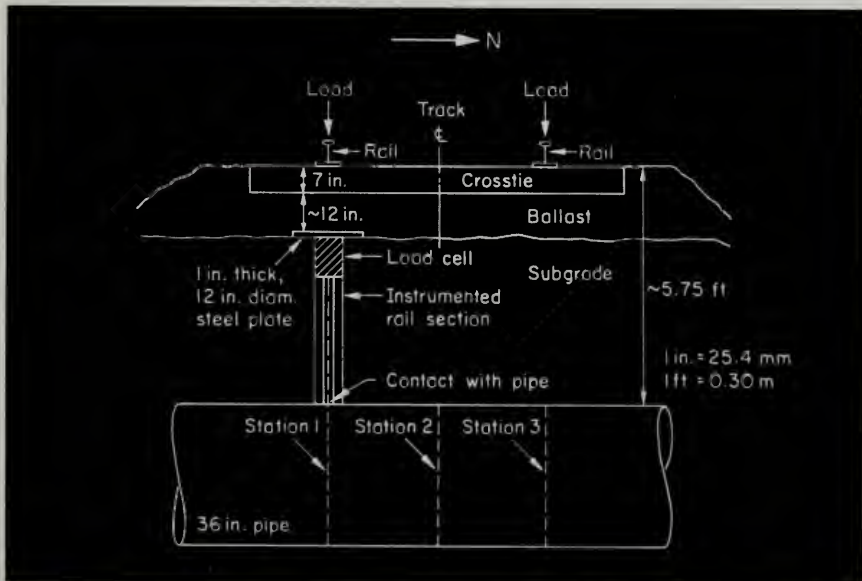
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While all of the members of the advisory committee were favorably impressed with the model, we all felt that field verification would be necessary, and we recommended that GRI consider a field test under actual railroad conditions. After much discussion GRI agreed to fund such a test and it was recommended that the best site would be under the FAST Heavy Tonnage loop at the Transportation Test Center near Pueblo, CO. We felt that a controlled environment such as FAST would give us the most accurate data and provide latitude for various additional testing if necessary.

After long negotiations between GRI, Cornell and the AAR, 12 and 36 inch diameter pipe sections were fabricated at Ithaca, New York. The Cornell group spent many hours, days, and months designing and testing a data acquisition system for taking the field measurements at FAST. The data acquisition system was very sophisticated and capable of taking many stress measurements from various critical locations on and inside the pipes and was coupled to a computer to process and store the data. After all this tedious work at Ithaca was completed, the pipes were shipped to Pueblo.

The instrumented pipe sections were installed under the heavy tonnage loop in July of 1988 by auger boring, which is typical of most installations under railroads. The work was performed by a pipe line contractor under the direction of the Cornell group and Rich Reiff, Manager of FAST Programs. The two pipes were installed 40 ft. apart with the 12" pipe 5.70 ft. below base of rail and the 36" pipe 5.80 ft. below base of rail. The 12" pipe was placed first and to obtain the desired overbore, a 0.75" overcutting band was welded on the leading edge except for about 60 degrees at the invert. The 36" pipe was placed in a like manner with a 0.61" overcutting band, and to further reduce friction, it was lubricated with a bentonite slurry. To simulate internal live loading both pipes were capped so they could be pressurized with water. It is interesting to note that the annulus around both pipes had to be grouted as the earth did not completely settle on the crown of the pipes even after considerable train traffic. This was necessary to make sure that maximum live loads were being transmitted to the pipes. Strain gage measurements were taken at the installation in July 1988, January 1989, May 1989, June 1989, July 1989, March 1990 and July 1990. During this time the test train was operated with 125 ton heavy axle load cars, and over 160 MGT were accumulated during data collection. As you will recall the purpose of all this field testing was to verify the computer model. The predictions of the model compared very well with the field measurements

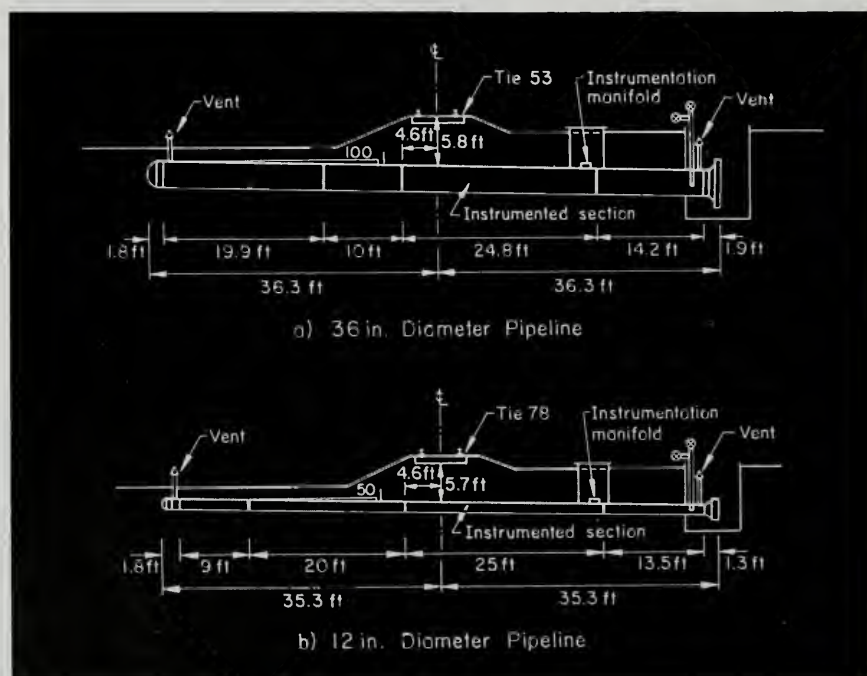


Cross section showing impingement test.

particularly in the area directly under the track. Two more phases of testing were performed at FAST, as impact factors had to be developed and verified. The railroad advisors were concerned with the possible loading of a carrier pipe with some impinging object such as boulders or other debris under the subgrade so an impingement test was authorized by GRI.

The impact testing was accomplished by progressively degrading the track quality over the 36" pipe and operating the train at various speeds. The track was degraded in three ways by creating irregular cross level up to maximum of 3.18", rail end mismatch up to 0.28" and joint gaps up to 0.94". The train speeds were always within the allowable for the appropriate FRA track class. The maximum speed was 40 mph and the minimum was 10 mph and the impact factors ranged from 0.8 to 1.6. The data collected suggested that larger impact factors might have been achieved at higher speeds, therefore an impact factor of 1.75 is recommended for burial up to 5.5 feet and decreasing to 1.0 at 30 feet. This conforms with the impact factor recommended by the API for pipelines under railroads.

The impingement testing presented a real challenge to the Cornell group and Rich Reiff's group at FAST. But together they came up with a very realistic worse case test. The impinging object consisted of a 136 lb. rail, torch cut on one end and fitted with a load cell and 12" diameter collector plate on the other end. The rail was installed with torch cut end directly bearing on the crown of the 36" pipe directly under the south running rail and the load collecting plate 12" below the tie at the interface of the subgrade and the ballast. To make this installation the south rail and several ties were removed along with a minimum amount of ballast. Then an 8" hole was air jetted through the subgrade to the top of the pipe and after the rail was placed it was back filled with native material and compacted as close as possible to the physical state of the undisturbed soil. The analysis of the field data collected during the test showed that under dynamic loads of 125 ton cars moving over the pipe, the highest stress in the pipe was only 4,470 psi at the crown, which is 2.7 times the highest stress (1,640 psi) previously measured at the crown. Under this load the pipe deflected 0.311". The stresses measured were well below the SMYS of the steel and the deflection value was well within the strictest deformation requirements, and resulted in no visible surface damage.



Cross sections showing details of 12" and 36" uncased pipe installations.

After completion of all the field tests at FAST the Cornell group spent many hours analyzing and studying the massive amount of data that was collected. The data did verify the computer model very well. All stresses measured in the field were well within the SMYS of the pipe steel. The final phase of the project involves the development of a design methodology for uncased crossings and a set of guidelines for the use of engineers in the gas pipeline and railroad industries. These guidelines will be coming later this year and I understand that GRI is planning to hold a series of workshops at various locations around the country to introduce them. Also a computerized version of the design methodology will be available for use on a PC.

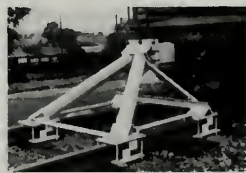
Now the big questions are, how does all this affect the railroads and where do we go from here? The design methodology developed by this project is very good. It is conservative and I feel that uncased crossings can be designed to carry railroad E-80 live loads. But there are other factors to consider. Statistics indicate that the majority of pipeline accidents are caused by "third party" damage and this is a major concern of the railroads and the pipeline industry as well. As I mentioned earlier Subcommittee 5 of Committee 1 has an assignment to develop specifications for uncased high pressure gas pipelines on railway right of way. You are probably asking, "Why we should even be considering this?" Indications are that the pipeline industry will continue to push harder for uncased crossings. There have been, as some of you may be aware, some condemnation suits concerning this issue and the lack of any governmental regulations requiring encased crossings makes it very difficult to justify encasement. I also feel that the pipeline people are going to make every effort to convince the ASME, ASCE and the Federal regulation agencies that uncased crossings are safer due to the problems with monitoring cathodic protection within casing pipes. I feel that it is in the railroad industry's best interest to come up with an uncased alternative in the AREA Manual on our terms rather than have some governmental agency mandate one. Please note

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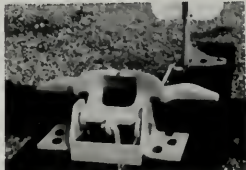
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that I said alternative, as there can always be situations where the only solution is a cased crossing. I think that the third party damage problem can be addressed best by deeper burial, although there are other alternatives such as thicker wall pipe, protective rock jackets and combinations of all three. As I mentioned before there are many, many old pipe line crossings under our railroads. As the pipeline companies replace them it could very well be best to consider an uncased crossing with deeper burial to give us more cover and more protection from third party damage as well as damage from a derailment or the cleanup of the derailment. Unfortunately, things like this can happen and have happened. Thank you very much. Now, I would like to turn this over to Bob Boileau for his comments concerning Subcommittee 5 activities and assignments.

Thank you, Jim. As Jim stated, I would like to outline the status of the assignments on which the pipeline subcommittee is presently working.

Assignment D5-2-81: Study the Use of Plastic Carrier Pipes. This assignment is approximately 50% complete at this time and should be completed in 1993. The use of plastic pipe by gas companies is becoming very commonplace for distribution and service lines. Plastic pipe does not corrode and is generally cost effective giving it advantages over its steel alternative. This pipe is generally used for pressures up to 100 psi and diameters up to 6". Several material types may be used, some of which are PVC (Polyvinyl chloride), FRP (Fiberglass Reinforced Pipe) and HDPE (High Density Polyethylene). Generally joints are made with bonded or epoxied couplings.

Several railroads presently allow the use of plastic pipe in sewer and water installations and also for natural gas and petroleum products pipelines. These lines should be encased in steel over the full R/W width or at least to some significant distance from operating trackage to help avoid damage from derailment or third parties on railroad property. A significant benefit of plastic carrier pipe is that no corrosion inside the casing will take place. It is envisioned by the subcommittee that other state or federal recommendations concerning the use of plastic carrier pipe will be referred to or adopted for use by AREA. These crossings must be encased and properly marked when on railroad R/W. With these constraints, safe occupancies can be obtained.

Assignment D5-3-91: Develop Recommendations for Uncased High Pressure Gas Pipeline Crossings has been discussed in detail by Jim Miller. Draft tables have been prepared which list pipe thicknesses for various internal pipeline pressures and grades of pipe material. These tables are similar in form to that of the present casing pipe table, and will allow the railroad engineer reviewing the application for crossing to quickly identify whether the pipe thickness is satisfactory. The assumptions made in developing the tables for items such as girth weld locations, depth, soil type, installation method, etc. are conservative, so the tables should apply for most installations.

This assignment will also include more stringent marking requirements. The use of signs will be recommended and marking tape laid in any portion of pipe which is open cut. Borings may be required if soil is of poor quality and additional analysis is required. A concrete jacketed pipe or protection slab will be recommended where threat of third party damage is a concern. In addition, the entire manual chapter will be reviewed for general application to today's conditions. This work is made more important due to the fact that the majority of the chapter is dated 1971. This has been brought up in several condemnations by gas companies, with the implication the specification is old and outdated and not current with today's materials, practices and engineering technology.

A few years ago, a rail-pipeline incident occurred in California. As a result of that incident, the State Fire Marshall's Office was directed by the State legislature to study and report on the construction of flammable pipelines within 500 feet of a railroad. This report should be completed within a month or two. These recommendations will be reviewed and incorporated into the AREA Manual if appropriate.

As stated earlier, both API and ASME are interested in the Cornell/GRI methodology. API currently is redrafting their Recommended Practice to be consistent with the new method. The new API Recommended Practice is expected this calendar year. We expect to have the new AREA Manual revisions, which are based on the new design methodology, ready for balloting by our Fall 1992 committee meeting.

Assignment D-5-92: An informational report on Directional Bores has been developed by the subcommittee. Directional Bores are typically driven several hundred to a few thousand feet in length at depths up to 30 + feet. The bore direction is often times computer controlled to miss obstructions or to bring the bore back on line after wandering slightly. These bores often cross under rivers, buildings, roadways, industrial facilities, and of course railroads. They may or may not include the use of casing pipe. Many permit requests for this type of installation have been received by railroads and they will increase as the method catches on. We have recommended that this report be published in an AREA bulletin.

Recently approved is Assignment D5-4-92, which concerns the use of overhead pipeline crossings. This topic is not covered in the existing Manual. Initial thoughts were discussed at our last committee meeting concerning items such as horizontal and vertical clearances, structural stability, supports, safety valving, and emergency preparedness. Recommendations in ballot form should be prepared in the next one to two years.

Another very important issue which will also be treated in the near future are longitudinal occupancies. The present recommendation is fairly general on this topic. More stringent and specific standards applicable to longitudinal occupancies of flammable material pipelines should be developed, especially in the area of cover over the pipeline and in emergency preparedness. Definitive communication channels and response should be established so that if a derailment occurs, each party knows how to react properly to the situation.

As you can see, we presently have several active assignments at this time. The next two years will be very busy for the subcommittee. We presently have about six active members in the group and can use more help. If you or someone in your organization would like to join the subcommittee, it would be greatly appreciated.

Jim and I are available to answer any questions you may have, either now or immediately after this morning session.

Thank you for your attention.

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COMMITTEE 1 - ROADWAY AND BALLAST

Chairman: W. L. Heide

INVESTIGATION INTO POTENTIAL CHEMICAL WEATHERING OF RAILROAD BALLAST

Chemical Weathering* of Primary Minerals in Igneous and Metamorphic Rocks:

General Principles:

Minerals occurring in igneous and metamorphic rocks such as granite, basalt, gneisses and schists have their greatest chemical and physical stability (or equilibrium) at the moment of crystallization. When these rocks cool and are exposed to the atmosphere many of the mineral constituents begin to chemically react with oxygen, water and carbon dioxide which is far more plentiful in the atmospheric environment than in the crystallization environment. These minerals also react with organic acids that are totally absent at the moment of crystallization. Quite simply, minerals are chemically changing to ultimately reach chemical equilibrium with the atmosphere, hydrosphere and, to some extent, even the biosphere.

The order of weatherability is related to the basicity of the mineral. Minerals that crystallize early use up most of the bases in the magma and are the first to react with surface elements. Notice also that the thermal differential between magma and atmosphere is greatest for these "early minerals." In addition, basic minerals such as plagioclase and pyroxenes have fewer strong silicon-oxygen bonds than alkali feldspars and biotite to ward off chemical attack (Ehlers/Blatt, p. 273).

Because of this principle of weatherability, many petrographers use Bowen's "Reaction Series," which is the order of mineral crystallization, as a weathering series in reverse. Actually, the "Weathering Series" by Goldich is almost the perfect reverse of Bowen's "Reaction Series" (see Figure 1).

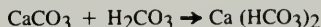
For example:

Olivine is the first to crystallize in a magma and is also the first mineral to weather.

Quartz is the last to crystallize in a magma and is also the most stable common mineral in igneous and metamorphic rocks.

The Chemical Dissolution of Carbonate Rocks:

The carbonate rocks (limestone and dolomite), although formed in a surface water environment, are more susceptible to chemical attack than is olivine. Their dissolution is usually the result of rain water and/or ground water mixing with carbon dioxide forming a weak carbonic acid (H_2CO_3). Carbonic acid reacts with carbonate rock forming calcium/magnesium bicarbonate ions that are carried away in solution.



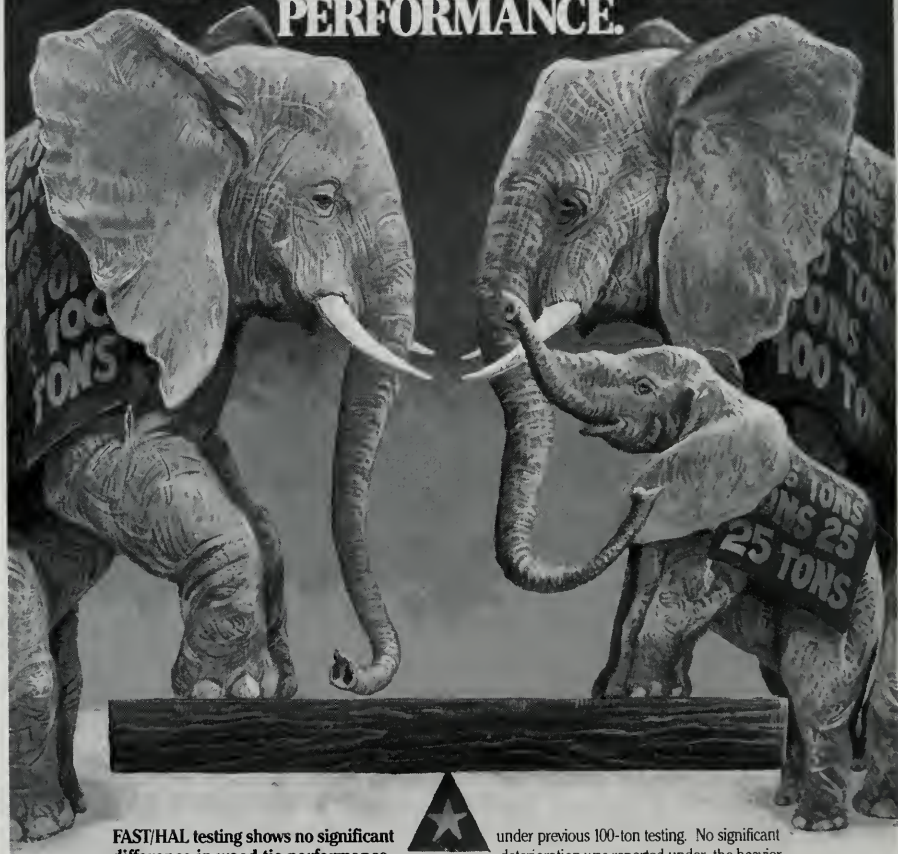
With regards to reactivity, limestone is regarded as more soluble than dolomite although some studies question this. The rate of limestone dissolution depends upon several factors including:

1. The area of solid-liquid interface (rock porosity, particle size, shape, etc.)
2. Kinetics (Ph, rate of water movement, CO_2 concentration in soils).
3. Equilibrium (unsaturated or saturated environment).

Note—For well drained ballast, the free flowing solution eliminates any possibility of saturation or an equilibrium being reached between solute and solution.

*Because the committee assignment is chemical weathering, use of the word "clay" refers only to clay minerals (see Appendix A).

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It should be noted that if a solution containing calcium-magnesium-bicarbonate ions undergoes some evaporation, then some carbon dioxide is lost causing precipitation of calcium carbonate. This is how stalactites and stalagmites are formed in caves.

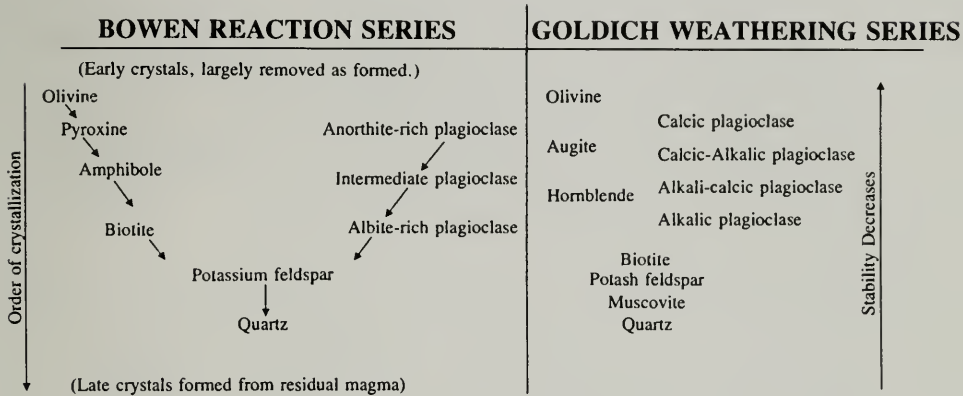


Figure 1

General Discussion of Studies Dealing With the Rate of Chemical Weathering:

A great number of studies have been published on the general subject of chemical rock weathering in terms of the chemical processes, the mineral alteration or dissolution of rocks and minerals and the geomorphic forms and products produced including soils.

Because of our assignment, the committee did review some of this literature but focused on the subject of Rates of Chemical Weathering. In this specific field much less work has been done due to the difficulty of measuring very slow processes in a quantitative sense.

Published studies fall into several categories:

1. Laboratory studies involving controlled conditions such as pH, mineralogy, surface area, temperature and liquid flow.
2. Hydrochemical balances in modern catchment basin studies where the chemical products from a single rock type are collected and measured in streams and lakes.
3. Weathering studies that investigate weathered crusts formed on dated geological materials such as glacial deposits.
4. Investigations that measure the rate of chemical transformation from bedrock (usually igneous) to saprolites and finally to soil.
5. Chemical studies of pyroclastics such as volcanic ash of known age.
6. Studies of rock cliff recession by marine action regarded as primarily chemical weathering.
7. Measurements of surface reduction caused by chemical attack on cultural objects of known age such as tombstones, walls and stone slabs.
8. Studies of surface reduction of natural stone pavements beneath soils that are protected against mechanical erosion but exposed to chemical weathering.

In order to get some impression of the rates of chemical weathering for various rock types, the following published studies are presented and referenced:

Rates of Chemical Weathering Igneous - Metamorphic

1. Nature of investigation—The rate of hornblende etching.
Determination— Less than 1 micron/1000 years.
Reference— Coleman, S.M. and Dithier, D.P., 1986. Rates of Chemical Weathering of Rocks and Minerals. Academic Press, Inc. p. 9.
2. Nature of investigation—The rate of saprolite formation from granite in Virginia Piedmont.
Determination— 1 cm/3000 years - or - 0.003 mm/year.
Reference— Pavich, M.J., 1986. Processes and Rate of Saprolite Production and Erosion on a Foliated Granitic Rock of the Virginia Piedmont, Chap. 23, Colman, S.M. et al.
3. Nature of investigation—The rate of saprolite formation from granite in the Southern Blue Ridge Mountains.
Determination— 3.7 cm/1000 years - or - 0.037 mm/year.
Reference— Velbel, M.A., 1986. The Mathematical Basis for Determining Rates of Geochemical and Geomorphic Processes in Small Forested Watersheds by Mass Balance: Examples and Implications, Chap. 18, Colman, et al. 1986.
4. Nature of investigation—The rate of weathering rinds development on basalt and andestite rock.
Determination— 5 microns/1000 years (Western United States)
Reference— Colman, S.M. and Pierce, K.L., 1981. Weathering Rinds on Andesitic and Basaltic Stones as a Quaternary Age Indicator Western United States. Geol. Surv. Prof. Paper (U.S.) 1210.
5. Nature of investigation—The rate of clay formation and mineral alteration of andesitic volcanic ash—St. Vincent Volcano, West Indies (4000 years old)
Determination— 45 to 60 cm/1000 years - or - 0.45 mm to 0.60 mm/year.
 Plagioclase (anorthite)—etched.
 Pyroxene and olivine—etched.
 Plagioclase (labradorite)—unaltered.
 Hornblende—unaltered.
Reference— Hay, R.L., 1960. Rate of Clay Formation and Mineral Alteration in a 4000-Year-Old Volcanic Ash Soil on St. Vincent, BWI, Am. Jour. Sci., 258, pp. 354-68.

Rates of Chemical Weathering Carbonate Rock—Not Pulverized

1. Nature of investigation—The surface reduction of limestone block by solution.
Determination— 0.04 mm/year surface reduction
Reference— Sweeting, M.M., 1966. The Weathering of Limestone. Essays in Geomorphology, Heinemann. London.
2. Nature of investigation—The reduction of carbonate rock surface by solution.
Determination— 40 to 50 mm/1000 years - or - 0.04 to 0.05 mm/year surface reduction.
Reference— Sweeting, M.M., 1973, Karst Landforms: New York, Columbia University Press, pp. 41, 42.

3. Nature of investigation—The surface reduction of limestone blocks by solution.
Determination— 0.5 to 1 mm/year surface reduction.
Reference— Hodgkin, E.P., 1964. Rate of Erosion of Intertidal Limestone. *Zeiff Geomorph* 8, pp. 385-92.
4. Nature of investigation—The determination of weathering rates for very old tombstones.
Determination— The number of years to produce 2.54 cm of weathering for 4 distinctly different carbonate rock types:
A. 500 years - or - 0.05 mm/year
B. 300 years - or - 0.085 mm/year
C. 250 years - or - 0.1 mm/year
D. 240 years - or - 0.1 mm/year
Reference— Goodchild, J.G., 1890. Notes on Some Observed Rates of Weathering of Limestone. *Geol. Mag.* 27, pp. 463-466.
5. Nature of investigation—The surface reduction by solution of limestone monument in Central Park, N.Y.
Determination— 3 to 5 mm in 90 years - or - 0.033 to 0.55 mm/year.
Reference— Winkler, E.M., 1978, *Stone Decay in Urban Atmospheres*, GSA, Engineering Geology Case Histories No. 11, p. 56.
6. Nature of investigation—The surface reduction by solution of Vermont Marble, South Bend, Indiana.
Determination— 1 mm/15 years - or - 0.07 mm/year
Reference— Winkler, E.M., 1978, *Stone Decay in Urban Atmospheres*, GSA, Engineering Geology Case Histories No. 11, p. 57.
7. Nature of investigation—The dissolution rate of limestone/dolomite in buried soil (7 year test) Igman Mt., Yugoslavia. Limestone with 3% insoluble residue.
Determination— 20 cm in 1.5 to 2.5 million years - or - .001 mm in 10 years.
Reference— Ciric, M. and Senic, P. 1985, *Intensity of Dissolution in Different Soil Media*, CATENA, Vol. 12, pp. 211-214.
8. Nature of investigation—The rate of surface lowering of Pleistocene carbonate rock by chemical weathering.
Determination— Low Mg calcitic rocks—0.35 mm/year
High Mg calcitic rocks—0.51 mm/year
Well cemented algal limestone—0.09 mm/year
Poorly cemented algal limestone—0.11 mm/year
Reference— Trudgill, S.T., 1976, *Rock Weathering and Climate: Quantitative and Experimental Aspects*: E. Derbyshire (ed), *Geomorphology and Climate*, Chapter 3, pp. 59-99, Wiley, London.
9. Nature of investigation—The surface reduction on fine-grained marble tombstone in South Bend, Indiana cemetery.
Determination— 0.7 mm/10 years - or - 0.07 mm/year.
Reference— Winkler, E.M., 1978, *Stone Weathering—A Literature Review*: GSA, Engineering Geology Case Histories No. 11, p. 59.
10. Nature of investigation—The depth of weathering on 50 year old Lincoln Memorial (studied in 1973).
Determination— 1.0 mm in 50 years - or - 0.02 mm/year
Reference— Sleater, G., 1978, *Development of Performance Criteria for the Selection of Stone Preservatives*: GSA—Engineering Geology Case Histories No. 11, p. 66.

11. Nature of investigation—The surface reduction of tombstones, Cave Hill Cemetery, Louisville, Kentucky.
- Determination—* 5 mm/100 years - or - 0.05 mm/year
- Study—* The zone of sulfation on tombstone, Cave Hill Cemetery, Louisville, Kentucky
- Determination—* Carrara Marble: 100 microns/100 years or 0.001 mm/year
- Study—* The zone of sulfation on tombstones, Field Museum of Natural History, Chicago.
- Determination—* Georgia Marble: 90 microns/66 years - or - 1.36 microns/year - or - 0.001 mm/year.
- Reference—* Gauri, K.L., Kulshreshtha, N.P., Punuru, A.R. and Chowdhury, A.N., 1989, Rate of Decay of Marble in Laboratory and Outdoor Exposures: Amer. Soc. Civil Engineering, Jour. of Materials in Civil Engineering, Vol. 1, No. 2, pp. 82-83.

The Chemical Weathering Effect of Metallic Sulfides Occurring in Carbonate Rocks:

Throughout the literature brief mention of the detrimental effect of sulfide minerals in carbonate rocks is reported. Most authors simply refer to the possibility of sulfuric acid being produced which in turn dissolves the carbonate rock.

Geochemist, Dr. Barry Maynard provided the balanced chemical reaction for pyrite oxidation as follows:



Maynard points out that the molar ratio between sulfur (in the pyrite) and calcium (in the limestone) is 1 to 2. Thus one atom of sulfur in pyrite could cause the dissolution of 2 molecules of limestone. (See Appendix B).

If we take this one step further, let us assume that the sulfur content of a typical carbonate rock is 0.1 percent and let us contribute all of this sulfur to pyrite. In this case 0.62 percent of the carbonate rock might be dissolved by sulfuric acid providing absolutely *all* of the pyrite in this rock was oxidized which is highly unlikely. Using this example as a standard, a very high sulfur content of 1.0 percent could cause a loss of 6.2 percent of the carbonate rock assuming 100 percent of the pyrite in the rock was oxidized.

It is Dr. Maynard's opinion that, for most carbonate rocks, pyrite does not contribute significantly to chemical weathering. However, carbonate rocks containing above 2 percent sulfur in the form of pyrite could be chemically damaged.

Summary of Committee's Conclusion Regarding Chemical Weathering of Railroad Ballast:

Based upon published research dealing with the rate of chemical weathering and upon consultation with five professional geological scientists, the committee has come to the following conclusions regarding chemical weathering in the ballast section:

For Igneous and Metamorphic Rocks

1. There is no evidence to support significant generation of clay minerals by chemical weathering of plagioclase or alkali feldspars, pyroxenes, amphibole, biotite or muscovite mica minerals within the life of any ballast section. This opinion is also extended to these minerals in fine sizes. Although fine particles provide substantially more exposed surface area, the rate of chemical alteration of primary minerals to crystalline clay in the weathering process remains insufficient to cause problems within the time frame between ballast placement and cleaning.

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2. Olivine is known to be the first common mineral in igneous and metamorphic rocks to chemically weather to limonite, hematite, clay mineral, and possibly serpentine. It is not certain if the weathering of olivine contributes significant quantities of secondary mineral products to cause ballast fouling during the life of the ballast bed. Olivine occurs primarily in basalt.
3. Micaceous chlorite found in igneous and metamorphic rocks is primarily of hydrothermal (deuteric) origin and thus may appear along with fresh ballast shipments. Micaceous chlorite is not a product of chemical weathering since it is a high temperature mineral. Micaceous chlorite should be avoided when selecting ballast sources since it is a soft hydrous layered silicate mineral.

For Carbonate Rocks (Limestone and Dolomite)

1. Research studies of the natural dissolution of carbonate rock surfaces (exposed bedrock pavement, monuments and cliffs exposed to wave action) suggest the amount of ballast size reduction by chemical attack would be insignificant during the life of the ballast bed.
2. The dissolution of carbonate rock fines in the ballast bed would be quite rapid due to increased surface area, rate of dissolution and the assumed free-flowing environment provided by a well drained ballast bed. Providing chemical equilibrium is not reached, the solute is believed to be rapidly removed from the ballast section and therefore does not contribute to a fouling problem.
3. An argillaceous carbonate rock is harmful to a ballast bed in two ways:
 - A. Clay minerals disseminated throughout the carbonate rock will hold water to the mineral surface by electrostatic attraction which leads to clay swelling in many cases. This clay swelling exerts internal stresses that cause aggregate failure leading to reduction in aggregate size and thus an increase in surface exposed to chemical attack.
 - B. The insoluble residue of rapidly dissolving carbonate rock fines commonly consists of clay materials such as illite which can, in sufficient quantity, contribute to ballast fouling.

Although most carbonate rock aggregates that have a low sodium sulfate soundness loss also contain very little insoluble residue, it is desirable to determine the percent of insoluble residue when selecting a carbonate rock ballast source. In order to further predict the potential mineral constituents of the insoluble residue, it is also necessary to determine the silica, alumina, potassium and sodium content of the host carbonate rock.

4. Metallic sulfide minerals such as pyrite are common constituents in carbonate rocks usually occurring in very small quantities. The determination of the abundance of these minerals can be somewhat implied by the sulfur content of the host rock. Because an excess of sulfide mineral oxidation could slightly increase dissolution of a carbonate rock, it is desirable to determine the sulfur content of a ballast source.

Sulfur content that does not exceed one percent in a carbonate rock is not regarded as detrimental to the chemical stability of the aggregate during the life of the ballast bed. Carbonate rock with sulfur contents exceeding one percent should be avoided as a source for railroad ballast.

Acknowledgments

The Committee wishes to express thanks to the following persons for their guidance and helpful counsel throughout this literature review:

To Dr. Warren Huff for his instruction in clay mineralogy, helpful suggestions and review of portions of this report.

To Dr. Paul Potter for his enthusiastic interest in the assignment and direction to appropriate specialists.

To Dr. Barry Maynard for explanations of geochemical processes and for contributing the section dealing with pyrite oxidation as a contributor to carbonate rock dissolution.

To Dr. David Nash for suggesting trace elements as a "finger-printing" technique to track sources of clay minerals.

To Mr. David Lienhart for directing the committee to significant recent literature dealing with chemical weathering.

References

- Bates, R. L. and Jackson, J. A., 1987, *Glossary of Geology*; American Geological Institute, Alexandria, Virginia, 788 pp.
- Carrol, Dorothy, 1970, *Rock Weathering*, Plenum Press, New York, 203 pp.
- Circic, M. and Senic, P., 1985, Intensity of Dissolution in Different Soil Media, *CATENA*, Vol. 12, pp. 211-214.
- Clay Mineralogy Identification; 1985, A Short Course, pub. by The Clay School, Denver, Colorado.
- Colman, S.M. and Pierce, K.L., 1981; Weathering Rinds on Andesite and Basaltic Stones as a Quaternary Age Indicator, Western United States; *Geol. Surv. Prof. Paper* 1210.
- Colman, S.M. and Dethier, D.P., 1986, Rates of Chemical Weathering of Rocks and Minerals, Academic Press, Inc., 603 pp.
- Curtis, C.D., 1976; Chemistry of Rock Weathering: Fundamental Reactions and Controls: E. Derbyshire (ed), *Geomorphology and Climate*, chap. 2, pp. 25-57, Wiley, London.
- Dana, E.S. and Ford, W.E., 1948, *Textbook of Mineralogy*, John Wiley and Sons, 851 pp.
- Ehlers, E.G. and Blatt, Harvey, 1982, *Petrology-Igneous, Sedimentary and Metamorphic*; W. H. Freeman and Company, San Francisco, 732 pp.
- Gauri, K.L., Kulshreshtha, N.P., Punuru, A.R. and Chowdhury, A.N., 1989; Rate of Decay of Marble in Laboratory and Outdoor Exposure: *Amer. Soc. Civil Engineering, Jour. of Materials in Civil Engineering*, Vol. 1, No. 2, pp. 73-85.
- Goodchild, J.G., 1890: Notes on Some Observed Rates of Weathering of Limestone; *Geol. Mag.* 27, pp. 463-466.
- Graham, R.C., Weed, S.B., Bowen, L.H., Amarasiriwardena, and Buol, S.W., 1989, Weathering of Iron-Bearing Minerals in Soils and Saprolite on the North Carolina Blue Ridge Front: II Clay Mineralogy, *Clays and Minerals*, Vol. 37, No. 1, pp. 29-40.
- Graham, R.C., Weed, S.B., Bowen, L.H., and Buol, S.W., 1989, Weathering of Iron-Bearing Minerals in Soils and Saprolite on the North Carolina Blue Ridge Front: Sand-size Primary Minerals; *Clays and Clay Minerals*, Vol. 37, No. 1 pp. 19-28.
- Grout, F.F., 1932, *Petrography and Petrology*, McGraw-Hill, Inc., New York and London; 522 pp.
- Hay, R.L., 1960; Rate of Clay Formation and Mineral Alteration in a 4000-year-old Volcanic Ash Soil on St. Vincent, BWI, *Amer. Jour. Sci.*, pp. 258, 354-68.
- Huff, W.D., 1983; Correlation of Middle Ordovician K-bentonites Based on Chemical Fingerprinting; *Jour. of Geol.*, Vol. 91, pp. 657-669.
- Hodgkin, E.P.; 1964; Rate of Erosion of Intertidal Limestone; *Zeiff Geomorph.* 8, pp. 385-92.
- Hudec, P.P., 1978; Rock Weathering on the Molecular Level: *GSA, Engineering Geology Case Histories* No. 11, pp. 47-51.
- Jack, R.N., and Carmichael, S.E., 1969; The Chemical "Fingerprinting" of Acid Volcanic Rocks: *California Div. of Mines, SR* 100, pp. 17-32.
- Kaye, C.A., 1957; The Effect of Solvent Motion on Limestone Solution: *Jour. of Geology*, Vol. 65, pp. 34-47.
- Keller, W.D., 1978; Progress and Problems in Rock Weathering Related to Stone Decay, *GSA, Engineering Geology Case Histories* No. 11, pp. 37-46.

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- Kolata, D.R., Frost, J.K. and Huff, W.D., 1987; Chemical Correlation of K-bentonite Beds in the Middle Ordovician Decorah Subgroup, Upper Mississippi Valley: *Geology*, Vol. 15, pp. 208-211.
- Kulshreshtha, N.P., Punuru, A.R. and Gauri, K. L., 1989; Kinetics of Reaction of SO₂ with Marble: *Amer. Soc. Civil Engineering, Jour. of Materials in Civil Engineering*, Vol. 1, No. 2, pp. 60-72.
- Leinhart, D.A. and Stransky, T.E., 1981, Evaluation of Potential Sources of Riprap and Armor Stone—Methods and Considerations, *Bull. Assoc. Engineering Geologists*, Vol. 18, No. 3, pp. 323-332.
- Leinhart, D.A., 1988, The Geographic Distribution of Intensity and Frequency of Freeze-Thaw Cycles, *Bull. Assoc. Engineering Geologists*, Vol. 25, No. 4, pp. 465-469.
- Ollier, Cliff, 1984; *Weathering*, Longman, London and New York. 270 pp.
- Pavich, M.J., 1986; Processes of Rate of Sapolite Production and Erosion on a Foliated Granite Rock of the Virginia Piedmont, Chap. 23—Colman, S.M. et al, 1986.
- Pettijohn, F.J., 1948, *Sedimentary Rocks*, Harper and Brothers, New York, 526 pp.
- Rudolf, Giovanoli; Schnoor, Jerald L.; Sigg, Laura; Stumm, Werner; and Zobrist, Jürg, 1988; Chemical Weathering of Crystalline Rocks in the Catchment Area of Acidic Ticino Lakes, Switzerland, *Clays and Clay Minerals*, Vol. 36, No. 6, pp. 521-529.
- Sleater, G., 1978; Development of Performance Criteria for the Selection of Stone Preservatives: *GSA—Engineering Geology Case Histories No. 11*, pp. 65-71.
- Sweeting, M.M., 1966; *The Weathering of Limestone. Essays in Geomorphology*, Heinemann, London.
- Sweeting, M.M., 1973; *Karst Landforms*; New York, Columbia University Press, pp. 41, 42.
- Trudgill, S.T., 1976; *Rock Weathering and Climate: Quantitative and Experimental Aspects*: E. Derbyshire (ed), *Geomorphology and Climate*, Chap. 3, pp. 59-99, Wiley, London.
- Velbel, M.A., 1986; *The Mathematical Basis for Determining Rates of Geochemical and Geomorphic Processes in Small Forested Watersheds by Mass Balance: Examples and Implications*, Chap. 18, Colman, S.M. et al, 1986.
- Wahlstrom, E.E., 1947, *Igneous Minerals and Rocks*; John Wiley and Sons, Inc., New York, 367 pp.
- Watters, B.R., Klassen, M.J. and Clifton, A.W., 1987; *The Evaluation of Ballast Materials Using Petrographic Criteria*, Session on Performance of Aggregate in Railroads, Transportation Research Board, Washington, D.C.
- Winkler, E.M., 1978; Stone decay in urban atmospheres, *GSA, Engineering Geology Case Histories No. 11*, pp. 53-58.
- Winkler, E.M., 1978; *Stone Weathering—A Literature Review: GSA Engineering Geology Case Histories No. 11*, pp. 59-61.

Appendix A—Differentiation Between the Terms “Clay” and “Clay Mineral”

Note—Definitions are taken from Bates, R.L. and Jackson, J.A., 1987, *Glossary of Geology*, Amer. Geol. Inst.

Clay

1. “A rock or mineral fragment or a detrital particle of any composition smaller than a very fine silt grain having a diameter less than 1/256 mm (4 microns). This size is approximately the upper limit of size of particle that can show colloidal properties.”
2. “A loose, earthy, extremely fine-grained, natural sediment or soft rock composed primarily of clay-size or colloidal particles and characterized by high plasticity and a considerable content of clay minerals and subordinate amounts of finely divided quartz, decomposed feldspars, carbonates, ferruginous matter and other impurities. Some clays are nonplastic. Clay should have more than 50% clay-size particles (Twenhofel, 1937, p. 96) and clay minerals must form at least one-fourth of the total (Pettijohn, 1957, p. 341).

3. "A term that is commonly applied to any soft, adhesive, fine-grained deposit (such as loam or siliceous silt) and to earthy material, especially when wet (such as mud or mire)."

4. "Clay mineral"

Notice—The four accepted definitions of "clay" range from that of strictly size with no reference to mineralogy, through an assortment of minerals, to strictly clay minerals.

Clay Mineral

Definition in Glossary of Geology, Bates et al

"One of a complex and loosely defined group of finely crystalline, metacolloidal, or amorphous hydrous silicates essentially of aluminum (and sometimes of magnesium and iron); they have a monoclinic crystal lattice of the two or three layer type, in which silicon and aluminum ions have tetrahedral coordination with respect to oxygen and in which aluminum, ferrous and ferric iron magnesium, chromium, lithium, manganese and other ions have octahedral condensation with respect to oxygen or hydroxyl. Clay minerals are formed chiefly by alteration or weathering of primary silicate minerals such as feldspars, pyroxenes, and amphiboles, and are found in clay deposits, soils, shales, alteration zones in ore deposits and other rocks, in flakelike particles or in dense, feathery aggregates of varying types. They are characterized by small particle size and ability to absorb substantial amounts of water and ions on the surface of the particles."

Brief explanation of Chemical Alteration from Primary Minerals to Clay Minerals:

The first event leading to the formation of clay in the weathering process is the leaching of such minerals as feldspars, amphiboles (hornblende) and pyroxenes (augite). The first product of alteration is a colloidal material without structure called allophane. Later the allophane is transformed into a structured crystal lattice consisting of sheets that combine to form layers.

Two types of sheets are formed:

Tetrahedral—made up of oxygen and silicon

Octahedral—made up of oxygen, aluminum, iron, magnesium and hydroxyl ions

Layers may consist of one tetrahedral sheet plus one octahedral sheet such as kaolinite or layers may consist of one octahedral sheet sandwiched between two tetrahedral sheets such as the smectite group that includes montmorillonite.

Different clay minerals will form as Ca, Na, K, Mg, Li and OH ions enter between the layers and, in some cases, also enter the sheet lattice. Because this movement is affected by several things including pH, a single primary mineral may chemically alter to several different clay minerals. However, generally the chemical composition of the primary mineral determines the type of clay mineral produced.

For example:

Orthoclase is a potassic feldspar mineral that commonly alters to potassic clay such as illite.

Plagioclase, amphiboles and pyroxenes are sodic and calcic minerals that produce clays such as montmorillonite.

Identification of clay minerals is done by X-ray diffraction. This procedure measures the thickness of the clay layer in angstrom units (one ten billionth of a meter) which is recorded on a diffractogram and interpreted by a clay mineralogist.

Without question the chemical alteration of primary minerals to clay minerals is a very slow process that is often discussed only in geological time units.

Appendix B—The Potential Dissolution of Limestone Caused by the Oxidation of Pyrite

Calculations provided by Geochemist Dr. Barry Maynard, Dept. of Geology, University of Cincinnati

Assume:

All of the sulfur in the limestone occurs in pyrite.

The total sulfur content of the limestone is 0.1%.

Reactions:



One pyrite dissolves 4 calcites.

One sulfur (in pyrite) dissolves 2 calcites.

Weights:

$$0.1\% \frac{0.1 \text{ g S}}{100 \text{ g rock}} \quad \bigg/ \quad \frac{32 \text{ moles S}}{\text{g S}} \quad \rightarrow \quad \frac{.0031 \text{ moles S}}{100 \text{ g rock}}$$

.0031 moles S dissolves $2 \times .0031 = .0062$ moles CaCO_3

$$\frac{.0062 \text{ Moles } \text{CaCO}_3}{100 \text{ g rock}} \times \frac{100.1 \text{ g } \text{CaCO}_3}{\text{mole } \text{CaCO}_3} = \frac{.621 \text{ g } \text{CaCO}_3}{100 \text{ g rock}}$$

Therefore:

0.62% CaCO_3 is removed from limestone by the total oxidation of 0.1% sulfur occurring in pyrite.



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MEMOIR

James G. Clark

James G. Clark died in Greenville, South Carolina on August 23, 1991.

Mr. Clark was born on December 23, 1913 in Kansas City, MO. He first attended Kansas City Junior College and subsequently entered the University of Illinois, earning a Bachelor of Science in Civil Engineering in 1935. He continued at the university as an Instructor while doing graduate work in Civil Engineering and received the degree of Master of Science in 1939. He continued teaching in the Civil Engineering Department and retired as a Professor of Civil Engineering in 1956.

During his tenure at the University of Illinois, and to strengthen his effectiveness as an engineering teacher, he obtained practical experience during the summers as a structural engineer with Curtis-Wright Corporation, Howard, Needles, Tammen and Bergendoff, American Bridge Company and Bethlehem Steel Company. During 1943-45 he served as a stress analyst for Consolidated-Vultee Aircraft Corporation.

Upon leaving the University, Mr. Clark devoted his time to the development of a structural engineering consulting practice, leading to the establishment of the firm of Clark, Dietz and Associates-Engineers Inc. of which he was President and General Manager. Upon retirement from that firm he subsequently founded ESCA Consultants, from which he had also retired prior to his death.

Mr. Clark became a Member of AREA in 1949 and was made a Life Member in 1989. He became a member of Committee 15, Steel Structures in 1957 and was named a Member Emeritus of that committee in 1988. During his service on the committee he contributed freely of his time, experience and resources and served for many years as Chairman of the Subcommittee on Bibliography and Technical Explanation. Because of his background in engineering education, he was also a helping hand to the younger members of the committee.

In addition to his service to AREA, Mr. Clark was also a Fellow of the American Society of Civil Engineers, and a Member of National Society of Professional Engineers, Illinois Society of Professional Engineers, American Society for Testing Materials, American Society for Engineering Education, American Welding Society, Sigma Xi, Tau Beta Pi and Chi Epsilon. Mr. Clark was a Member of the Professional Engineers Examining Committee, State of Illinois from 1959 to 1974 and a Member Emeritus of that Committee from 1974 until his death. He was a Registered Structural Engineer in the State of Illinois and a Registered Professional Engineer in eight states.

Mr. Clark is survived by his wife, Janice Winters Clark, of Greenville, South Carolina, four daughters and one son, seventeen grandchildren and six great-grandchildren.

*Dan S. Bechly
November 17, 1991*

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MEMOIR

T. Robert Kealey

T. Robert Kealey, age 70, retired Managing Partner of Modjeski and Masters Consulting Engineers, died August 3, 1991 in Wormleysburg, Pennsylvania.

Mr. Kealey graduated from Drexel Institute of Technology, and Massachusetts Institute of Technology. He was listed in "Who's Who in the World," and was well known and honored in the engineering world. Many major bridge projects were under his direction during his career including the Walt Whitman Bridge in Philadelphia, the Greater New Orleans Bridge, and the Newburgh-Beacon Bridge over the Hudson River.

He became a Member of the American Railway Engineering Association and AREA Committee 8 "Concrete Structures and Foundations" in 1960, a Life Member upon his retirement in 1988, and was given the distinct honor of Member Emeritus of Committee 8. He was a Fellow of the American Society of Civil Engineers, Member of National Society of Professional Engineers, International Bridge Tunnel and Turnpike Association, and American Consulting Engineers Council.

As a member of the Applied Technology Council he assisted in the preparation of the ATC-6 Guide Seismic Specifications for the Federal Highway Administration, and published a paper on the effects of the October 1989 Loma Prieta Earthquake upon railroad structures in AREA Bulletin No. 727. At the time of his death, he was Chairman of AREA Committee 8 Subcommittee 5 "Design of Concrete Components for Bridges in Seismic Zones." As Chairman, Mr. Kealey was responsible for development of the first national specification for Pier Protection Systems for bridges over navigable waterways, an AREA specification used as a prototype for subsequent specifications by other parties.

Mr. Kealey was the ruling elder of the Paxton Presbyterian Church, and is survived by his wife Rita R. Kealey, his son Jay Kealey, daughter Carol Ann Steckbeck, sister Sybil Persley, and three granddaughters.

Mr. Kealey, well known in the industry, will be sorely missed as a professional and friend of all that knew him.

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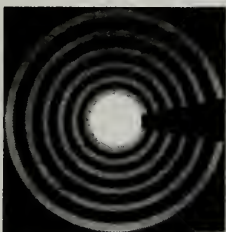
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OCTOBER 1992

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Stefanie Streever, Editor

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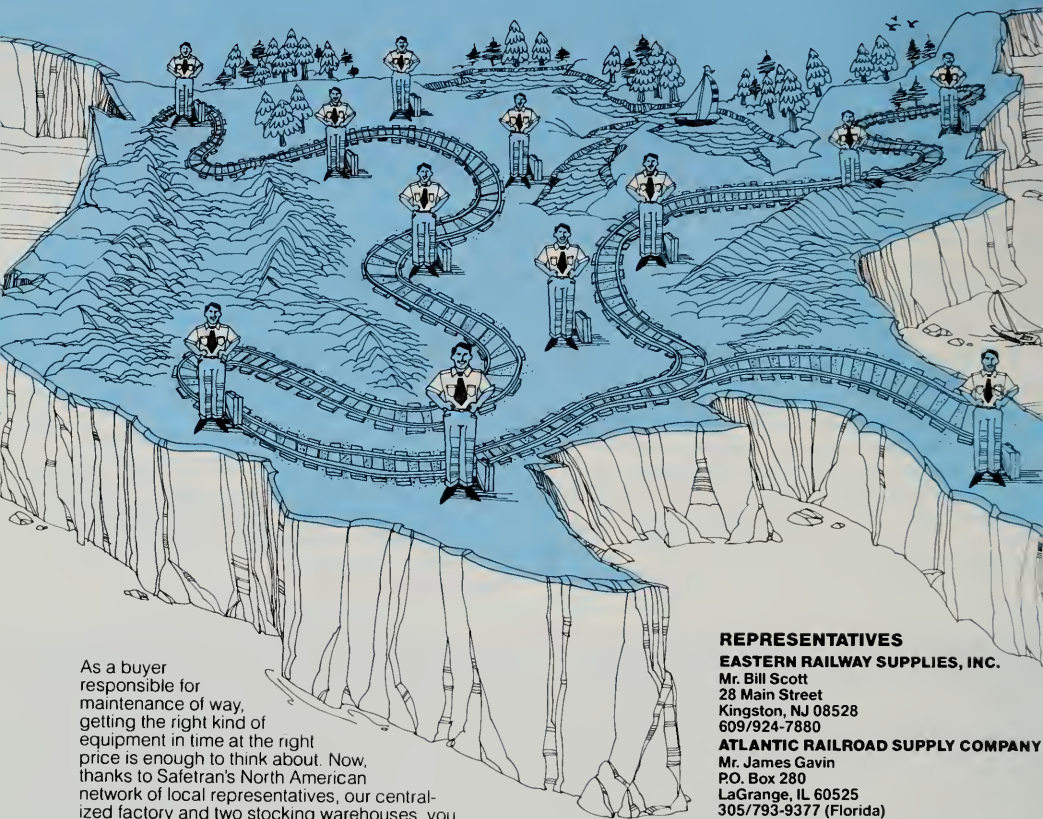
MORE WITH LESS

While in the past it was common for huge yard facilities to exist where major railroad systems met to exchange traffic, with today's unit trains, run through power, and good coordination between railroads providing seamless service to shippers, such exchanges can take place at locations with minimum yard facilities.

Such is the case with interchange between the Norfolk Southern and Conrail for North-South traffic along the East Coast. Formerly, most traffic was interchanged at the vast Potomac yard complex in Alexandria, Virginia. The trains of one railroad were disassembled and resorted into other trains on the connecting line. Now the interchange often takes place at a small yard in Hagerstown, Maryland. The container train on Conrail shown arriving in the photos above and on the cover pulled to a stop and within a few minutes was on its way south with the new Norfolk Southern crew. The same train is shown below accelerating southward on Norfolk Southern a few miles south of the city.



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CLEARANCES FOR DOUBLE STACK TRAINS

LINE CLEARANCE FOR USE OF DOUBLE STACK TRAINS IN MEXICO

By: Carlos Davalos*

RAILROAD TRANSPORTATION DEVELOPMENT IN MEXICO

Products Transported by Railroad

Today's railroad transportation has applications for high freight volumes at long distances, as well as for the massive passenger movement at considerable speeds and distances.

In Mexico, 95% of the railway services are for goods movement and only 5% for passenger transportation! This is mainly due to difficult layouts in diverse mountain regions of the Mexican territory.

The major products moved by the railway system are: grains, automobile and electronic parts that come from the U.S. and Canada destined to collection centers in the middle of the country; milk and other food products from Europe thru Gulf of Mexico ports headed to inner country consumption centers; and agricultural items, mineral products and sulfuric acid that are transported to Pacific ports for exportation. From the northeast agricultural centers, vegetables are carried to the United States border. From the central and northern regions of the Mexican Republic export assembled automobile units are moved in unit trains to the United States. Also, important beer volumes are transported to the northern border. On internal system tracks iron, coal, as well as chemical and industry oil products are moved.

Rolling Stock Used

To meet the freight service demand for products to be moved, the National Railways of Mexico utilizes 24,000 wagons, 17,000 gondolas, 2,500 flat cars, 1,600 tank cars, 1,000 cage cars and 500 refrigeration cars. In addition to this standard equipment, and due to the interchange with American and Canadian railways, more specialized freight units are running on the National Railway's tracks such as hopper cars, high capacity jumbo tank cars, 3 rack level flat cars for automobile transportation, high

*Special Project Coordinator, National Railways of Mexico



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volume box cars for automobile parts transportation, piggy back flat cars, and in recent years, special flat cars for double stack service.

Trends on Traffic of Products

Due to commercial opportunities at international levels and technological advances in goods transportation in the last decade, service requirements have been modified from the traditional movement of basic industry raw materials to the handling of delicate and expensive electronic products and automobile part finished products. This requires modern rolling stock, efficiency and adaptability to the different transportation needs. Container use has provided the means for an integrated door-to-door service.

INTRODUCING THE INTERMODAL TRANSPORTATION IN NATIONAL RAILWAYS OF MEXICO

Background

Today's products are focused to supply a worldwide market. The intermodal system has ample application to the modern market providing quick distribution, especially when product interchange takes place between countries. Important aspects during transportation are handling care and security of the product, especially when different transportation modes such as air, highway and sea are also used.

Piggy Back System Transportation

Since the 1970's, the intermodal system used on the National Railways of Mexico was 'Piggy Back,' which was also being used in the United States and Canada. This system allowed for quick movement of the merchandise combining railroad and road transportation for delicate, perishable and highly valued products. To provide this service the Mexican Railways acquired a fleet of 500 special flat cars and 300 box cars to mainly transport fruits, vegetables, beer and electronic products from Sinaloa's region to the Nogales border in Arizona along the Pacific route.

The piggy back service for transportation of either export or import manufactured products was established from the center region of the country to the North along the Mexico-Monterrey-Laredo and Mexico-Ciudad Juarez corridors, obtaining satisfactory results and important annual growth rates.



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Use of Containers

Containers are the elements which have proved to be the best in intermodal handling for valuable merchandise in the international and national ambits. In any of its variations, sea-road or road-railroad-highway, intermodal offers considerable economical advantages compared to traditional transportation systems of bulk merchandise or individually packaged products.

National Railways of Mexico container usage started on a reduced scale in 1975, increasing gradually until the 80's and more rapidly in the last two years.

Double Stack Container Transportation

To reduce costs and to make the railroad transportation more efficient in competing with highway transportation, containers for two levels in railroad flat cars were designed. During the beginning of the 70's the first prototype equipment was constructed using low-boy flat cars as a base, interarticulated in groups of five units with couplers at the end of each group. Based on this, the container placement was studied so that in the lower bed of each flat car two short 20 ft. containers could be placed, and on the upper bed one long container could be accommodated being either 40, 45, 48, or 53 ft. in length.

Container dimensions have been standardized according to sea transportation, with a low cube of 8'6" high and 96" wide and a high cube of 9'6" high and 102" wide. When placed on double stack equipment they require a minimum of 18 and 20 ft. in respect to the rail head for their clearance, and when combining low and high cube containers clearance must be 19 ft. high and 102 in. wide.

On the Mexican National Railways implementation of double stack service was planned and projected for two lines in 1989. The first line consisted of inland routes to and from the United States borders. The second line was from the central plateau to the ports. This planning was based on the potential demand from a market survey that showed important transportation needs of double stack containers on the Chicago-Laredo-Mexico City, Los Angeles-El Paso-Mexico City and Detroit-Nogales-Hermosillo routes.



Two level containers on a railroad flat car help reduce costs of transportation.

In 1990 the first unit trains with this modality were put into service which was coordinated with various connecting U.S. railroads and other transportation companies. This service has had very positive results as it is based on preestablished schedules. The expected growth rate of this service for the next five years is 100 percent.

Generally, the commodities handled with this system for the importation market are: automobile parts, chemical products, canned foods, construction materials, powdered milk, electronic and manufacturing products among others. For the exportation market some commodities are: automobile parts, foods and beverage, paper, glass and plastic packings, furnishings, computers, bicycles, coffee, tobacco, detergents, tires, and yeast.

To establish double stack service in our country it was necessary to carry out a previous survey conducted on the main routes that evaluated and determined the proper requirements to allow double stack trains through tunnels and bridges that used to have restrictions.

It is important to point out that the advantages obtained from the double stack service have been higher than those obtained with the intermodal service of single stack container movement and piggy back. This is because almost the total amount of the Mexican National Railways network is single track. Double stack movement moves double the volume of merchandise per unit track length, which means higher productivity and efficiency as well as an easier, safer movement of a lower number of trains.

VIABILITY OF DOUBLE STACK TRANSPORTATION ON THE MAIN MEXICAN RAILROAD ROUTES

Clearance Revision of the Tracks on the National Railways of Mexico

In 1989 a feasibility study of double stack transportation was made. A clearance inspection program of all lines was done, updating the existing clearance information and details for tunnel and bridge sections—especially in the 10 ft. wide central zone required for double stack equipment. The clearance



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updating was done utilizing manual measurements backed up by cars adapted to obtain the heights and widths of each section. Clearance information was complemented and verified for some of the most important lines with laser beam clearance detection equipment contracted through the Union Pacific Railroad.

Line Load Capacities

In a similar way, to upgrade routes for double stack movement, a load capacity study of the railroad network was done. This study included bridges and culverts, as well as the structural conditions of the track, even though the double stack equipment initially planned for operation did not produce effects higher than that caused by 100 ton car unit trains. Based on this survey a reinforcement program for bridges and culverts was put into effect to increase their capacity, thus standardizing them at a minimum Cooper E-72 load. In cases of reconstruction or integral reinforcement of these structures, a Cooper E-80 load was achieved with an adequate operation margin for future load increases in railroad equipment.

Regarding track structural capacity, a program covering the main part of the basic network is being carried out, with only high caliber 115 lb./yd. to 136 lb./yd. continuous welded rail installed with elastic fastenings, mainly on concrete ties. Upon completion of work done during 1990 and 1991, restrictions for high tonnage equipment on some of the main routes was able to be cancelled.

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Bridge carrying capabilities on the system were assessed.

CLEARANCE ENLARGEMENT PROGRAM

Short Term Program

A short term program was developed in consideration of all main routes where clearances had to be enlarged in the shortest possible time. The programmed time was 8 months and included the following routes:

Laredo-Mexico City, Monterrey-Matamoros, Piedras Negras-Salttillo, El Paso-Mexico City, Mexico City-Guadalajara, Nogales-Mazatlan, Mexico City-Veracruz, Toluca-Celaya, Torreon-Monterrey-Tampico, Coatzacoalcos-Salina Cruz, Mexicali-Benjamin Hill, Mexico City-Coatzacoalcos and Coatzacoalcos-Merida.

In the cases mentioned above, the clearance modifications were not of a considerable magnitude so it was possible to carry them out within the appointed term with small investments according to a budget. (See Table No. 1).

Medium Term Program

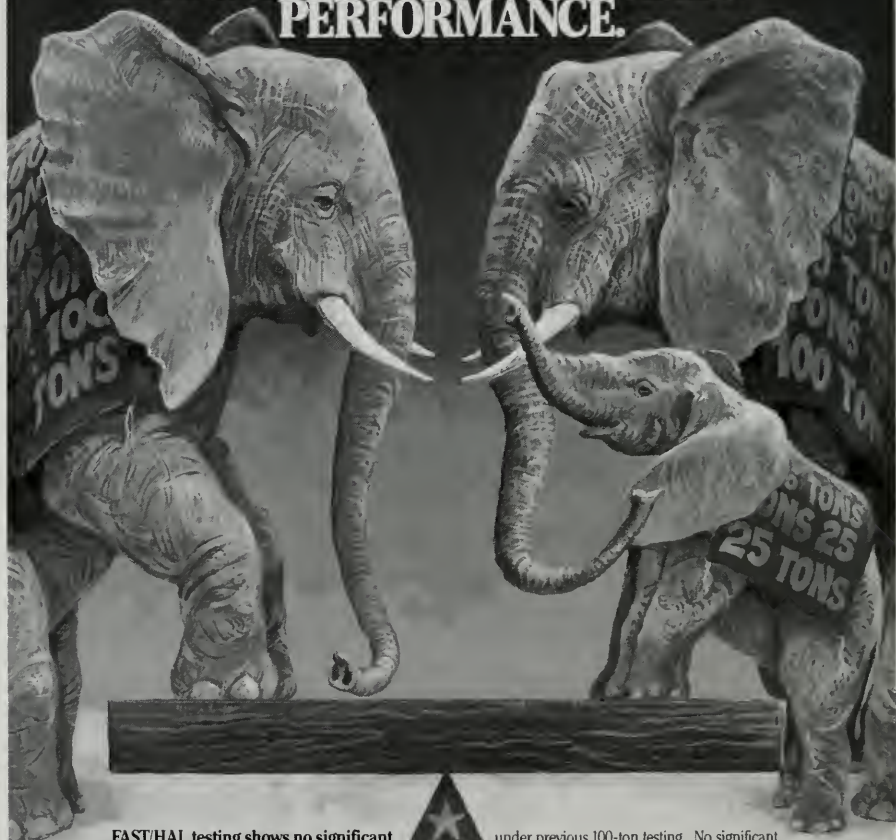
This program encompasses all routes with double stack service that may be delayed until 1995 and involves clearance alterations involving important expenses and longer working times.

The main routes contemplated for this program are: Irapuata-Lazaro Cardenas, Guadalajara-Manzanillo, Mexico City-Coatzacoalcos, Celaya-San Luis Potosi, Saltillo-Monterrey and San Luis Potosi-Tampico. (See Table No. 2).

Long Term Program

This program includes routes with major difficulty to alter the clearances as well as those where double stack service demand is low. Due to the difficulties that these modifications imply, the cost is much higher and its timetable is extended until the year 2000. The principal routes for this stage are: Chihuahua-Topolobampo, Guadalajara-Mazatlan, and Ixtepec to the Guatemala border. (See Table No. 3).

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Table No. 1
Clearance Enlargement Short Term Program

Stretch	Length (KM)	Work	Time	Investment (Mill US \$)
Laredo-Mexico City	1,290	2 Bridges 8 Tunnels	8 Months	1.9
Monterrey-Matamoros	330	2 Bridges	2 Months	0.1
Piedras Negras-Salttillo	436	2 Bridges	2 Months	0.1
El Paso-Mexico City	1,970	3 Bridges	3 Months	0.5
Mexico City-Guadalajara	612	1 Bridge	1 Month	0.1
Nogales-Mazatlan	1,175	2 Bridges	2 Months	0.2
Mexico City-Veracruz	471	1 Bridge	1 Month	0.1
Mexico City-Toluca-Celaya	354	2 Bridges 2 Tunnels	4 Months	0.4
Torreon-Monterrey-Tampico	898	2 Bridges	2 Months	0.2
Coatzacoalcos-Salina Cruz	303	2 Bridges	2 Months	0.2
Mexicali-Benjamin Hill	524	1 Bridge	1 Month	0.1
Mexico City-Coatzacoalcos	710	5 Bridges	8 Months	0.9
Coatzacoalcos-Merida	895	2 Bridges	3 Months	0.2
TOTAL →	9,894	27 Bridges 10 Tunnels	8 Months	5.0

Table No. 2
Clearance Enlargement Medium Term Program

Stretch	Length (KM)	Work	Time	Investment (Mill US \$)
Irapuato-Lazaro Cardenas	528	1 Bridge 14 Tunnels	7 Months	2.5
Guadalajara-Manzanillo	359	16 Tunnels	10 Months	3.0
Celaya-San Luis Potosi	204	1 Bridge	1 Month	0.1
Saltillo-Monterrey	111	1 Bridge 1 Tunnel	4 Months	0.4
San Luis Potosi-Tampico	444	6 Tunnels	6 Months	1.1
TOTAL →	2,360	3 Bridges 37 Tunnels	5 Years	7.1

Table No. 3
Clearance Enlargement Long Term Program

Stretch	Length (KM)	Work	Time	Investment (Mill US \$)
Chihuahua-Topolobampo	674	50 Tunnels	4 Years	10.0
Guadalajara-Mazatlan	590	35 Tunnels	4 Years	7.0
Ixtepec-Guatemala Border	460	3 Bridges	6 Months	0.4
TOTAL →	1,724	3 Bridges 85 Tunnels	10 Years	17.4



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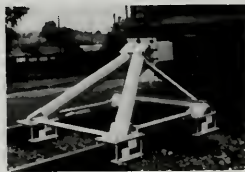
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CLEARANCE ENLARGEMENT METHODS FOR TUNNELS

Minor Cuttings and Finishing of Sections

From the detailed inspection of tunnel clearances from measurements taken at each 20 meter distance, some irregularities were detected and needed to be eliminated to ensure a standard clearance envelope that was set for a safe operation of the double stack equipment. Clearance tolerances of 1 ft. in height and 6 in. in width measured to the container's corner were used. In this way the minimum height required in the tunnel ceiling would 6.40 meters (21 ft.).

In most cases, the irregularities in the tunnel rock were not larger than 3 ft. and could be eliminated using excavating tools worked from the roof of specially equipped wagons, and with the limited use of explosives.

Undercutting Method

Undercutting was the most commonly used procedure to improve clearances along all routes. Where it was necessary to reduce between 4 and 8 inches, the total ballast bed was eliminated using a ballast undercutter cleaner to cut the necessary length. The end crests were also cut, laying the clean new ballast with a calculated thickness to match the new track elevation.

When track lowering deeper than 8 in. was required and the floor material was of soft rock, it was possible to excavate with an undercutter up to 20 in. under the tie, removing the ballast and cutting a part of the floor with the chains of the machine.

In cases of track lowering deeper than 20 in., as with the "Butterfly Tunnel" between Saltillo and Monterrey which was up to 55 in., it was necessary to dismantle the track, rake the ballast away with tractors and make floor excavations down to 45 in. In hard rock, drilling and the use of duly controlled explosives to avoid damages to walls and tunnel lining was required. Close coordination with the operations department to use the track during predetermined periods was necessary to avoid important traffic problems. In the Butterfly Tunnel traffic was stopped for 74 continuous hours since the cutting of the floor rock was about 30,000 cubic ft. in a length of 1000 ft. In this particular project, we previously built new embankments for the approach portions to make the connections to the new track in the tunnel in the minimum possible time, taking into consideration the new track elevation.

In some future track lowering we are planning to eliminate the ballast, laying the rails directly on reinforced concrete slabs.

Cutting on Arch Lining and Unlined Tunnels

In many tunnels with a clearance limitation the procedure to follow for their enlargement was arch cutting, using drills and controlled blasting to obtain small reductions, especially on unlined tunnels. For lined tunnels the lining was first removed. Then, an additional cut in the rock was performed to reach the desired section. Later, the lining was rebuilt. For important arch cuttings, in either lined or unlined tunnels, the use of tunnel grinding machines have been contemplated to ease and speed up the work.

With this procedure clearance widening for 16 tunnels on the Guadalajara-Manzanillo line are included that are currently hindering double stack operation. Clearance improvement of this portion is required before the end of 1995 as part of the medium term program, and its work will be performed through a contract.

Tunnels Converted Into Open Cuts

Clearance widening has been programmed for short length and reduced depth tunnels by completely opening the section, as made in two tunnels in the old layout on the Mexico City-Orizaba-Veracruz line. This procedure will also be applied in some scarce clearance galleries, where it will be necessary to lower the cuttings to obtain stabilization and their later elimination.



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Grinding machines are used for arch cuttings in tunnels.

PROCEDURES FOR BRIDGE CLEARANCE ENLARGEMENTS

The hindrances of bridges for double stack traffic have been minor and easily handled compared to those in tunnels. In cases where restrictions have appeared in through truss bridges, the lack of clearance is located in the brackets or gussets of the portals of the bridge. These portals have been modified by elevating the brackets or cutting the gussets.

In very few cases we have seen that the height on the clearance of the low through truss is so reduced that correction is difficult. Truss substitution is a consideration, being suggested by a rather low bridge capacity.

We have seen cases where the height of the beams at highway crossings and at elevated track crossings has trouble with double stacks. At these locations it has been necessary to uplift these superstructures.

ADAPTED ROUTES FOR DOUBLE STACK TRANSPORTATION

Due to completion of the "Butterfly Tunnel" enlargement located between Saltillo and Monterrey, the Laredo-Mexico City route is now in operation for a 1,290 kilometer double stack direct service. Also, the El Paso-Mexico City route with a length of 1,970 kilometers and the Nogales-Hermosillo route with 280 kilometers are in operation.

After completion of the short term program the jobs remaining to be done for the clearance enlargement were relatively easy and quick. To date, the following routes are ready to take double stack service: Monterrey-Matamoros, 330 kilometers; Piedras Negras-Salttillo, 436 kilometers; Mexico City-Guadalajara, 612 kilometers; Nogales-Mazatlan, 1,175 kilometers; Mexico City-Jalapa-Veracruz, 471 kilometers; Toluca-Celaya, 280 kilometers; Torreon-Monterrey-Tampico, 898 kilometers; Coatzacoalcos-Salina Cruz, 303 kilometers; Mexicali-Benjamin Hill, 524 kilometers; and Coatzacoalcos-Merida, 895 kilometers.

CLEARANCE ENLARGEMENT LINES IN PROCESS, FUTURE ENLARGEMENTS

Among the routes classified for the medium term program currently underway are: Irapuato-Lazaro Cardenas, 528 kilometers; Mexico City-Coatzacoalcos, 714 kilometers; and Celaya-San Luis Potosi, 204 kilometers.

Other medium and long term program sections are being studied, with the specified completion periods according to service demand and estimated budgetary plans.

DOUBLE STACK TRAFFIC RESULTS

This railway transportation modality has been accepted with optimism by the National Railways of Mexico's main customers, even though it has only recently been offered. Nowadays, 60,000 double stack containers are handled annually, mainly in unit trains to Mexico City from El Paso and Laredo, Texas.

When this service was initiated we were skeptical regarding its success because the runs would be made on tracks with a more difficult layout than those in the United States (12 degree curves). Fortunately, no derailments or other important mishaps spoiling the benefits of this important service have ever occurred.

The success obtained with this railway innovation in Mexico, which represents a maximum advantage for the tracks installations and equipment, is encouraging us to speed up the enlargement programs and the clearance modifications on the National Railways network. No doubt double stack service will be one of the main income sources for the National Railways of Mexico in the near future, benefiting the industry and the country as a whole.

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RESTORATION OF CSX BRIDGE AT SHEPARDSVILLE

By: R. W. Thompson, Jr.*

At approximately 12:30 p.m. November 19, 1991, a garbage truck with an inexperienced driver was instructed to make a detour from the normal route to pick up one additional resident's garbage. The 12'-2" high garbage truck attempted to go under CSX's underpass 5A (see photo below), which had a vertical clearance of 10'-6" and is located only 300 feet south of the Salt River Bridge. Although double track, each track of the underpass was supported by an independent bridge span. The two-beam-per-rail "I" beam span supporting the northbound track was heavily damaged and knocked horizontally 11-1/2 inches.

CSX's bridge # 5 over the Salt River is located within the city limits of Shepardsville, Kentucky, on the Main Line Subdivision, 18.7 miles south of Louisville, Kentucky. The Main Line Subdivision carries 26 million gross-tons of traffic and is a direct connection between Louisville, Kentucky and Nashville, Tennessee.

A short time after the garbage truck struck underpass 5A, northbound freight R526/19 rounded the curve just south of the underpass and not having sufficient distance to stop, attempted to negotiate the disturbed track section. The resulting 27 car derailment collapsed the northern two spans of CSX's Bridge # 5 over the Salt River and heavily damaged the remaining span. Bridge # 5 was a three span, double track, thru truss structure with each of the spans measuring 152'-1".

Fortunately all three locomotives negotiated the disturbed track, remained on the rail, traveled across the bridge ahead of the derailed equipment and came to rest north of the bridge. The crew was not injured.

To complicate matters, a television crew which was filming on location near the Salt River Bridge at the time of the derailment was able to supply CNN with some spectacular coverage. As a result of the



12'-2" garbage truck attempts CSX's 10'-6" underpass.

*Director, B & B Maintenance, CSX Transportation

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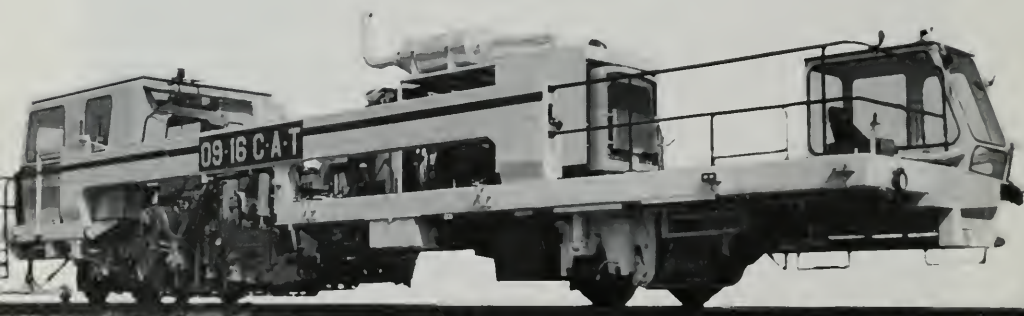


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sensational nature of the derailment and the graphic details of the footage, CSX was forced to suspend trading of its stock for a short period of time on November 20, 1991.

This was not the first time the Salt River Bridge had to be replaced under emergency conditions. During the Civil War, Confederate troops had burned the bridge on three separate occasions.

An assessment of the situation was made by CSX officials and 66 federal, state and local agencies. It was determined that the two critical shipments in the derailed consist were a tank car of Propylene Oxide and a boxcar containing cluster bombs returning from Desert Storm. The tank of Propylene Oxide was in a derailed position on the heavily damaged south truss while the boxcar of cluster bombs turned over, was partially over the bank about 150 feet south of the bridge. One of the mangled cars in the collapsed portion of the trusses contained Methylene bisPhenyl Diisocyanate which leaked into the Salt River. Since the chemical hardened and became a solid mass in water, it never threatened the environment.

Of immediate concern was the safety of the local population and the clean-up personnel. An area one mile in diameter with 2500 local residents was evacuated and a command location was established for the emergency response agencies.

It was quickly determined that the span under the northbound track of the underpass and the two northern truss spans of the Salt River Bridge were destroyed. The south truss span, although heavily damaged, could be repaired. The south truss span had an end post, one hanger, three diagonals, one end of a floor beam, top stringer laterals and the entire deck of ties damaged so severely that they had to be replaced or repaired before traffic could be allowed over the bridge.

As wrecking operations got underway, CSX's Engineering Department developed a restoration plan taking into consideration time, cost, manpower, material, equipment, and location requirements. It was determined that the most cost effective solution would be to single track and TCS a nine mile section which included the derailment location. The northbound track was selected to be the new single track. December 6, 1991 was projected as the completion date for all bridge, track and signal work.



Twenty-seven car derailment collapsed the northern two spans of CSX bridge over the Salt River.

By constructing a single track bridge with four deck plate girder spans instead of the destroyed two truss spans, secondhand spans in stock at CSX's bridge fabrication shop at Barboursville, West Virginia, could be modified and used as replacement spans. Two of these secondhand spans were modified and new shoes built to provide proper vertical dimensions. These two spans were immediately shipped to the jobsite. The second two spans required more ingenuity. Four welded-deck-plate-girder spans were on hand but they would not rate for main line operation. These four spans were cut apart and new laterals, lateral plates and diaphragms were fabricated to use the existing welded girders as two girder per rail spans. In this manner the four existing secondhand spans ended up as two replacement spans in the new bridge. All design and detailed drawing work, including piers, was performed in house by CSX's Bridge Design Office.

All modifications to secondhand spans and fabrication of repair steel were completed by twelve B&B employees at the bridge fabrication shop. The fabricated repair steel was trucked to the jobsite and the four steel spans were moved by special train directly from the shop to the jobsite.

From inception to design to completed fabrication, 500,000 pounds of bridge steel was delivered to the jobsite in 14 days. Even with the large amount of work and the short period of time, all fabricated steel fit and the bridge went together as detailed.

Simultaneous with the fabrication of repair steel and replacement spans, a local contractor was awarded a contract to construct the two new piers and set all four of the replacement spans. The new piers were keyed 12 inches into existing bedrock and heavily reinforced — designed to stay. Class "M" concrete which had a minimum cylinder break of 4800 psi in 24 hours was used exclusively in both new piers. The two piers were completed in a total of four days.



An elaborate restoration plan began, taking into consideration time, cost, manpower, material and location.

Once the piers were completed, the two northern spans were delivered and erected by the contractor, including placement of the ties. The rail was installed by CSX crews. The track was required to be in place on the two northern spans so that the remaining two spans could be spotted on flat cars as close as possible to their final position in the bridge.

Once the derailed equipment was cleared from the south truss span, CSX bridge crews proceeded to remove the twisted and mangled steel in preparation for the repair steel being fabricated at Barboursville. The original restoration plan was so thorough that the order in which each piece of repair steel was to be fabricated was considered. As certain sections of repair steel were fabricated, they were trucked to the jobsite and were usually being placed in the structure within 24 hours.

Due to the complete destruction at northeast panel point L1, the floorbeam had to be spliced at the centerline of the northbound track. Also at this location, hanger U1-L1 along with diagonals L1-M1 and L2-U1 had to be replaced.

At the south end of the truss span, the west end post sustained considerable damage and was bent out of alignment horizontally 18 inches. At the same location diagonal L1-M1 was damaged beyond repair. Considerable finesse was required to repair this end post and diagonal.

The underpass beam span which was initially destroyed by the garbage truck was replaced with an identical span taken from the southbound track of an underpass about 300 feet North of the Salt River Bridge. To take the place of the original timber bearings, blocks were cast from the same class "M" concrete delivered for the piers.

All repair work on the south truss and the replacement of the underpass was carried out with CSX crews and equipment.

During the seventeen days of work, Mother Nature was not a happy camper. It rained, snowed, sleeted and one day the wind chill was 7 degrees below zero. The Salt River also flooded on two occasions. CSX had very good cooperation from the Corps of Engineers who kept the dam 60 miles upstream closed until the setting of the last span.

In addition to the restoration work at the Salt River Bridge and at underpass 5A, 7200 track ties, two # 20 power operated turnouts and two # 10 turnouts were installed. The signal system for the nine miles of single track was completed by the time the bridge was opened, just two weeks and three days after it all began.

A project of this magnitude with such limited time requires complete teamwork between all departments involved. CSX is fortunate not only to have employees capable of performing the tasks involved, but also employees who desire to work together toward a common goal.

One of the greatest compliments that can be made to the men and women who designed, fabricated and erected 240 cubic yards of concrete, 456 bridge ties, all of the above itemized track and signal work, and one half million pounds of structural steel in 17 grueling days, is that there were no personal injuries on this project.



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Tour of European High Speed Rail Systems

May 27-June 8, 1991

By: Richard G. McGinnis*

Introduction

The purpose of this presentation is to give an overview of the findings of AREA Committee 17's 2-week tour of European high speed rail systems. Our group inspected systems under construction in Spain and France and systems in operation in France, Italy, Germany, and Sweden. What we saw in each country is summarized below.

Spanish National Railway (RENFE)

RENFE (Spanish National Railway) is in the process of building its first high speed rail line. The first AVE (Alta Velocidad Española) line will cover the 471 kilometers from Madrid to Seville. In October 1986 the government announced the decision to construct the new line. Construction began in October 1987 and the line is scheduled to be opened on April 19, 1992, the day before the opening of the World Exposition in Seville. The infrastructure is being designed for an operating speed of 250 kph (156 mph) although the TGV-like rolling stock is capable of operating speeds of 300 kph (186 mph). The new high speed line has no grade crossings but does have 31 viaducts totalling about 10 kilometers in length. The lower height viaducts are constructed of prestress concrete girders with pier caps that wrap around the girders for lateral stability.

Seventeen tunnels were constructed on this line using the Austrian tunneling method. Sixteen tunnels were through natural terrain, and one was an above ground tunnel which was constructed to reduce noise in an adjacent residential area. The tunnels have a 5.82 meter radius giving a cross sectional area of 75 square meters which is slightly larger than the 72 square meters used on the older French TGV lines and is smaller than the 84 square meters for German ICE. The Spanish studied the piston effect through tunnels quite extensively before deciding on this design.

Dual block concrete ties are used on the ballasted track. Thirty centimeters of ballast is used under the ties, and the tracks are on 4.3 meter centers and use rail weighing 60 kilograms per meter.

Turnout ties are fabricated with alignment markers which are part of the KGO (Kinematic Gauge Optimization) system that is used by tampers to determine proper alignment. The ties also have a clip in the center to fix the cab signal cable. Insulated joints employ reinforced ductile iron joint bars and the rail joint is cut to a 30° angle.

Crossovers are constructed every 20-25 kilometers at an estimated cost of about \$350,000. They are designed for a line speed of 250 kph and a crossover speed of 160 kph (100 mph). The movable point frogs are made in a single forging with the point rail butt-welded onto the frog. They use a length compensation joint where longitudinal forces are transferred from the running rail to the wing rail through thrust blocks.

Each turnout has 8 switch machines that operate simultaneously. Extended tie plates are used for purposes of attaching the motor housings. Provisions are made on the switch rod attachments to compensate for longitudinal displacements of the rail. The extended tie plates also allow the switch operating mechanisms to be attached on either side. On all switch ties the bolts go through the tie with a nut recessed on the tie bottom which allows bolt changeout and puts the concrete tie in compression in the rail seat area.

The signaling system provides a tolerance of plus or minus 6 meters for locating the position of trains in the system. They have a constant information system that is updated every .8 seconds and all interlocking is done electronically. Speeds are monitored by central control, and if an operator does not

*Associate Professor of Civil Engineering, Bucknell University

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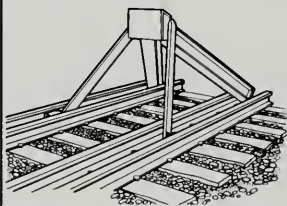
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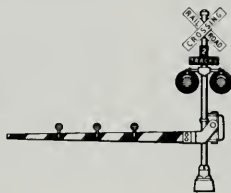


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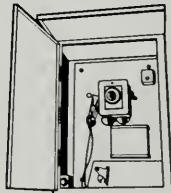
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reduce speed or exceeds the speed limit, automatic braking occurs. However, drivers do control the train unless they violate a speed limit.

Signal and communication cables are carried in a duct along the track right-of-way. Junction boxes are provided periodically. On structures, easy access to the duct is provided through a channel with precast concrete covers. Concrete signal relay houses are located where necessary. Security is provided by a 6-foot high right-of-way fence.

The electrical system uses 25 kilovolt, 50 Hz electricity. A constant-tension catenary system employs counter weights that provide the constant tension on the running wire regardless of temperature. Catenary poles are precast concrete with all necessary holes predrilled. To install the catenary poles, metallic tubes are driven to a depth of 5 meters, and the tubes are extended about 1/2 of a meter inside of the hollow catenary poles. The hollow concrete poles are then filled with liquid concrete.

Prior to building the new high speed line, the RENFE system used a track gage wider than that used on the rest of the European continent. In December of 1988, a little more than a year after construction on the AVE began, Spain made the decision to adopt the standard European gage for their new high speed line. This decision to change the gage affected other lines resulting in a total of 2,000 kilometers of new track that was required. During the construction process, work trains travel to the new line using the wider Spanish gage. When they get to the new line their axles are replaced so that they can operate on the standard gage high speed track. In station areas where new conventional tracks are being constructed, they are using a specially designed tie which can accommodate either gage width. If and when the decision is made to convert the rest of the Spanish rail lines to the standard gage, transition will be easier in the areas where these new ties are used.

Since the 1980's, the Spanish have operated the Talgo Pendular tilt train. This passive tilt train operates at a maximum speed of 200 kph (125 mph).

French National Railways

The French TGV Southeast line from Paris to Lyon has been in operation since 1981. On this highly successful line, trains travel at 270 kph (168 mph) over the 390 km (242 mile) long distance. Passenger revenues are approximately 2-1/2 times the operating cost for the line. Trains on the newly-opened TGV Atlantique line operate at a speed of 300 kph (186 mph). In addition to the 436 miles of operating high speed lines, SNCF is currently constructing an additional 594 miles (957 km) some of which is designed for operating speeds of 200 mph (322 kph). Their master plan calls for 14 additional new lines totalling 1,880 line miles (3027 km). While the maximum operating speed for the TGV is 300 kph (186 mph), a record speed of 515 kph (320 mph) was obtained during testing on the newly opened Atlantique line.

The TGV Atlantique train sets are maintained at the Chatillon Maintenance Facility in Paris. TGV maintenance is based on the "preventive" concept and varies with each type of equipment. The maintenance schedule for TGV Atlantique equipment includes certain daily inspections, service inspections every 1,000 miles on high speed lines, preventive maintenance every 2 to 4 days, detailed running gear inspection every 9 days, and 3 levels of routine maintenance every 3 months, 6 months, and 18 months respectively. This schedule will be modified as more operating experience is gained with the equipment. The average annual mileage per train set is 250,000 miles and the total maintenance cost is in the order of \$1.20 U.S. per train mile.

The TGV train sets are somewhat lighter because of an articulated design which allows two cars to share the same bogie or truck. The maintenance facility is equipped with a series of remote controlled jacks operating on rails that are capable of lifting an entire train for maintenance. Each TGV truck has four disc brakes which are controlled electronically so that all the brakes activate at once. Each axle is equipped with a wheel slip protection system which compares the four axles of each car and assures that no axle is slipping while braking.

The train sets feature modular construction which makes component replacement very easy. Accessibility to the components was a high priority in the vehicle's design. The trains are controlled by a single operator who uses a circular device similar in appearance to a steering wheel to accelerate and decelerate the train. Analog gauges provide operating information to the driver.

The environmental concerns were given high priority by the designers of the system. The air cushion suspension system gives the passengers a very comfortable ride. Interior and exterior noise has been reduced to low levels. The exterior noise level at 25 meters (82 ft.) from a TGV operating at 175 mph is 81 dBA with a noise wall, and 90 dBA without a noise wall.

Since the majority of the TGV lines pass through rural areas, provisions have been made for livestock crossings underneath the rights-of-way. Safety nets are provided in areas around all highway bridges so that obstacles falling from bridges will be detected and trains can be stopped if necessary.

The TGV trains are equipped with a dual electrical system which allows them to operate on both the 25 kv-50hz high speed lines and on the 1,500 volt conventional lines. The high speed lines are also equipped with reverse signaling to allow travel in either direction on both tracks.

The original TGV Paris-Lyon line was built without a single tunnel even though it runs through the Morvan Mountains. Since the TGV lines are restricted to passenger trains only, maximum grades of 3.5% are used. The Lyon-Valence line which is currently under construction has 5.3 km (3.3 miles) of tunnels and 4.4 km (2.8 miles) of elevated structures. For the line's total length of 121 km (75.1 miles), the average cost for the infrastructure is \$14 million per mile. For the 62 miles (100 km) of line that are not on structure or in tunnel, the average cost drops to about \$10 million per line. The La Cotiere viaduct is just over one mile long as it crosses the Rhone Valley. Tunnels on the new lines have a radius of 6.3 meters and an open area of 100 square meters. These tunnels are significantly larger than the ones on the older TGV lines and allow for more comfortable travel at higher speeds. The new Lyon-Valence line has an intermodal station at the Satolas International Airport which services Lyon. Trains not scheduled to stop will pass through this station in an enclosed structure running through the center of the station.

For the newer TGV lines, the normal horizontal curve radius is 6,000 meters ($D=0.3^\circ$), but a minimum curve radius of 4,000 meters ($D=0.45^\circ$) is used on an exceptional basis.

SNCF indicated that dual block concrete ties are used because they are 36% cheaper than monoblock ties and also provide greater lateral resistance in the ballast. Thirty-five (35) centimeters of ballast is used under all dual block concrete ties. The standardized elastic fastener for SNCF is the Nabla clip which gives a creep resistance greater than 20 kN per rail.

Annual maintenance for the passenger-only TGV track costs about \$13,000 per track mile. Track maintenance on SNCF conventional lines is more than 3-1/2 times as much or about \$47,000 per track-mile. On the TGV lines, no ballast replacement is expected to be needed before 1995 and no rail replacement before the period 2000 to 2010.

Italian Railways (FS)

Because many of its current lines are saturated, Italian National Railways is in the process of developing a high speed rail network. The present project calls for a total network of 1,000 kilometers (621 mi.) at a projected cost of \$22 billion including rolling stock. New high speed lines have been built for eighty percent of the 262 km (162 mi.) Rome-Florence line. Since 1988 the ETR-450 Pendolino trains have been operating between Rome and Florence. The ETR-450 is a tilting technology produced by Fiat Ferroviaria. The tilt is activated by the first axle of the train and can be as great 8° .

The high speed line is electrified with 3,000 volts dc which is the same as that used on conventional Italian lines. On the Rome-Florence line the minimum horizontal radius is 3,000 meters with a maximum superelevation (cant) of 110 mm (4.3 in.) The subgrade width is 12 meters with track centers at 4.3

meters. Maximum speed on the current line is 250 kph (156 mph) although 300 kph (186 mph) is the design speed for future lines.

The new Italian lines are designed for mixed use of freight and passengers with axle loads up to 22.5 tonnes (24.8 tons). The maximum grade is 1.8% which is reduced to 1.5% in tunnels because of the increased aerodynamic resistance in tunnels. Because of the rough Italian terrain and the flat grades required for freight operations, many tunnels have been constructed. Older tunnels have a cross sectional area of 58 square meters while new construction will be either 85 or 90 m². The typical new tunnel has a radius of 5.7 meters. On the 100 km Bologna-Florence line, 60% will be tunnels at a cost of \$48 million per mile, 10% will be viaducts at \$16 million/mi and the 30% at grade at approximately \$5.6 million/mi excluding equipment costs.

An 11-car ETR-450 train set costs approximately \$23 million while the new experimental ETR-500 costs about \$36 million. The new ETR-500 will be capable of speeds up to 300 kph and is a non-tilt technology.

Deutsch Bundesbahn (DB) Intercity Express (ICE)

The German Intercity Express (ICE) began revenue service on June 2, 1991 between Munich and Hamburg. The ICE trains operate at a speed of 250 kph (155 mph) over new sections of track and at 200 kph (125 mph) over conventional rail. The maximum length train of 14 cars provides seats for 192 first class passengers and 567 second class passengers. The carriages were designed with the passenger's comfort and convenience in mind. Larger seats, audio-modules for headphones, conference compartments, electric typewriters, photocopiers, telefax, and onboard telephones are a few of the features that have been incorporated into the ICE. In addition, one carriage in both the first and second class sections features video monitors in the backrests of the seats.

All of the German railways operate both freight and passenger service. Consequently, the new high speed lines are designed to standards that will accommodate freight trains as well as high speed passenger trains. Because of the freight operations, the maximum grade on the new lines is only 1.25%. The freight trains also require a lower maximum superelevation (cant) of 85 mm (3.3 in) which compares to a maximum cant of 180 mm (7.1 in) for the passenger-only French TGV. On an exceptional basis, the Germans do allow the cant to reach 150 mm (5.9 in.).

Because of the lower superelevation, flatter curves are necessary to accommodate the high speed passenger service. The desired minimum horizontal radius for the German system is 7,000 meters ($D=0.25^\circ$) compared to the minimum desired radius of 6,000 meters on the newer TGV lines. The minimum horizontal radius on the German system is 5,100 meters compared to 4,000 meters on TGV.

Combined with the hilly German terrain and environmental constraints, the flat grades required for freight operations necessitated the building of many tunnels on the new lines. Thirty-seven percent (37%) of the 327 km (203 mi.) line from Hanover to Wurzburg is in tunnel and 33% of the 99 km (62 mi.) line from Mannheim to Stuttgart is in tunnels. For passenger comfort, the ICE trains are pressurized to reduce the passenger's discomfort associated with passing through tunnels at high speeds.

The power supply for the ICE trains is 15,000 volts, 16-2/3 hz which is used to supply the 4,800 kw locomotives. The catenary structure utilizes precast concrete poles which are similar to those used in the new Spanish AVE system.

Where possible, train control is totally automatic through a cab signal system that uses both rail and inductor signal data collection and transmission. As with the new Spanish system, the cab signal cables run over the tops of the concrete ties centered between the rails. Track centers of the ICE new lines are at 4.70 meters and the subgrade width is 13.7 meters.



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The engineer's cab of the ICE incorporates more advanced digital and video features than do the other high speed locomotives observed. Included in the controls available to the operator are 2 video displays which selectively can be used to display a range of information including individual brake status, current braking performance, required stopping distance, and other important operating parameters. The locomotives for the ICE trains sets and Spanish AVE are being manufactured by Krauss Maffei in Munich. German locomotive manufacturers have formed joint ventures to produce rail equipment.

Specialized track components for most of Europe's high speed rail systems are manufactured by BWG. In BWG's Butzbach facility, turnouts are preassembled and match marked. Each turnout is carefully fabricated and inspected before being disassembled and shipped. One of BWG's leading technology concepts is the 31" long transition section of the asymmetric heel rail's cross section to the cross section of the closure rail. The low profile asymmetric switch rail is forged to the full profile UIC-60 closure rail. Ultrasonic testing is used for quality control. The switch point rail extends under a spacer block separating running rails which prevents the point from lifting. The close tolerances for high speed turnouts necessitate a stringent quality control program which the German track manufacturers have been able to achieve.

Swedish State Railways (SJ)

Unlike the other European high speed rail systems, the Swedish are not constructing new track for their high speed trains. Their philosophy is to design a train that is capable of operating at reasonably high speeds on existing infrastructure with very modest improvements in track standards. Furthermore, the high speed passenger service will share space with freight and commuter services.

To accomplish their goal, Swedish rail has studied carefully the track train dynamics that are responsible for safety, wear, and running stability. Their research indicates that the lateral force on the leading outer wheel in a curve is the force to examine. This force is the sum of the flange force on the outer wheel and the friction force on the inner wheel. This research led to the development of a self-steering radial truck which is one of the important components of the new Swedish X-2000 high speed trains system.

The other component in the X-2000 system that makes higher speeds possible is the active tilting of the cars in curves to compensate for the centrifugal force that is generated. These improvements make possible a 25-30% higher speed through curves than can be obtained by conventional equipment. This new technology will make it possible for SJ to reduce the travel time between Stockholm and Gothenburg from 4 hours to 3 hours. The increased speed is accomplished without any compromise of safety or comfort.

The active tilting system on the X-2000 reduces the centrifugal force by approximately 80%. The maximum effective car body tilt is 6.5° and the tilting mechanism is activated only at speeds above 70 kph. While the vehicles are capable of maximum speeds of 210 kph, the maximum operating speed is set at 200 kph (125 mph). Axle loads reach a maximum of 17.5 tons. The vehicles were designed and built by ABB (Asea Brown Boveri).

Since the X-2000 operates on existing track, the track geometry encountered is significantly different from those of the European systems discussed previously. The minimum horizontal curve radius is 1,000 meters with 600 meters as an exception. Speeds of 180 kph (115 mph) are possible on curves with a 1,000 meter radius ($D=1.75^\circ$). Because of the less stringent track geometry required for the X-2000, this technology shows the greatest potential for use in the United States in the short-term. In the near future, Amtrak will be testing the X-2000 on the Northeast Corridor. The Swedish geography requires that the X-2000 be able to perform under a wide range of environmental conditions. The arctic winter conditions of northern Sweden and the summer conditions of southern Sweden specify a wide range of requirements for the X-2000.

Swedish lines do have a few highway grade-crossings. Sensors are placed on the highway approaches to the grade crossing to detect any intrusion of the space between the detectors and the track. If an intrusion occurs, this information is relayed through the signal system to the train operator.

Summary of Major Findings*

- The most important factor affecting track standards is whether or not freight trains will operate on the high speed tracks.
- Construction costs are affected by maximum allowable track grade, curvature requirements, terrain restrictions, environmental considerations and property costs.
- High speed operation above 150 mph requires large radius curvature of 11,000 ft. (6,835 m.) ($D=0.5^\circ$) or flatter.
- Tilt train technology can offer under certain conditions an increase in speed of 20 to 30 percent over conventional equipment without major track alignment changes.

APPENDIX**Members of the Committee 17 Delegation**

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Gene E. Ellis, Amtrak
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European Hosts

ABB (Asea Brown Boveri)
BWG (Butzbacher Weichenbau Gesellschaft)
DB (Deutsche Bundesbahn)
Krauss Maffei
FS (Italian Railways)
RENFE (Spanish National Railways)
Siemens AG
SJ (Swedish State Railways)
SKF Bearing Industries
SNCF (French National Railways)
Swedish National Rail Administration

*These findings are those of the author and do not necessarily represent the views of AREA Committee 17 or of the other members of the high speed rail delegation.

VISTA TUNNEL BYPASS PROJECT NEAR WHITEFISH, MONTANA

By: S. A. Millsap*

The line change and resulting bypass around Burlington Northern Railroad's Vista Tunnel, was a very ambitious project that not only felt the constraints of a relatively short work window, but also had to be constructed in concert with today's environmental concerns and working adjacent to a tunnel with questionable structural integrity. This was a \$3-million project that required approximately 6 months of engineering and design by Shannon & Wilson, Inc., Geotechnical Consultants; approximately 4 months of permitting; environmental impact review; land acquisition, and 3 months of actual construction.

The Vista Tunnel is located on Burlington Northern main track approximately 7 miles west of Whitefish, Montana. Whitefish, as many of you may know, is located at the north end of the Flathead Valley just east of Glacier National Park. This main line corridor, connecting Seattle and the Twin Cities, carries 45 MGT of intermodal, grain and mixed freight traffic annually.

The tunnel was driven by hand through a ridge of glacial till in 1904 as the Great Northern constructed a better route westward toward Spokane, Washington. The ridge creates a drainage divide between Whitefish Lake, less than a mile to the east, and Boyle Lake, 300 yards to the west of the tunnel. Top of rail elevation of track in the tunnel is 5-10 feet above that of the water surface in Boyle and Whitefish Lakes. The tunnel is 840 feet long and has approximately 85 feet of overburden over it. The east end of the tunnel is curved to accommodate the west spiral of a 3 degree curve. The balance to the west is tangent. The tunnel was originally lined with timber. Due to early problems with the tunnel, it was concrete-lined 8 years later in 1912 and 1913. The lining is reinforced concrete with 21-inch thick walls and a 15-inch thick crown. Plans show that a 12-inch reinforced floor was to have been included in the lining work.



Photo 1. Double stack train travels through east portal of Vista Tunnel.

*Superintendent, Maintenance of Way, Burlington Northern Railroad

1946 is the first record we have indicating that there was a problem with the invert of Vista Tunnel. That year, severe mud pumping into the ballast was reported. In 1951, an inspection revealed cracks had developed in the east portal and also in the south wall just below the spring line. Again, it was reported that the ballast was fouled and exploration proved that the reinforced concrete invert had been omitted during the 1912 lining work. In 1953, concrete struts were placed at the east portal to stabilize the footings and walls. That same year, the fouled ballast was removed for a depth of 3 feet below the top of tie and a 2-foot thick layer of sand and cement mix was placed to form an invert or floor. Clean ballast was reapplied.

In 1955, the ballast in Vista Tunnel was muddy again and deep ditches were proposed to drain water from the south wall at both the east and west portals in 1956. Mud and pumping persisted so grouting was performed in an attempt to stabilize the soil condition. In 1957, a retaining wall was constructed at the east portal to support the unstable hillside and to keep the ditch open. In 1958, the track was pumping again and the ballast was full of mud. A line change bypassing the tunnel to the south side was proposed. The proposed line change was approximately 10 thousand feet long and was estimated to cost 583 thousand dollars not including land. Because of budget constraints, the proposal was postponed until 1966 when 133 acres of land were purchased in preparation for a line change.

In 1972, track surface and mud had gotten so bad that, again, the mud and ballast had to be removed. A heavy polyethylene membrane and a layer of sand was placed under new crushed rock ballast. A new timber drain box was constructed along the south wall. In 1973, consideration was given to placing a precast concrete invert, but concerns of how effective the joints between the slabs would be caused this proposal to be dropped.

In 1975, Shannon & Wilson, Inc., was employed to make a study of the problem and to furnish recommendations. In 1976, Shannon & Wilson recommended that drains and ditches be installed just

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west of the tunnel to intercept water and to provide drainage for both ground and surface water. This work was done in 1977. In 1978, a study was made that indicated the sand and cement invert was crack riddled and that mud was pumping through the cracks into the ballast section. In 1980, the track was once again muddy and pumping. Again, the track and ballast were removed along with the polyethylene that had been installed 8 years earlier. A geotextile fabric was installed as a filtering layer between the crack-riddled sand and cement invert and new ballast. At the same time, 9 drainage sumps were placed along the south wall as recommended by Shannon & Wilson, Inc., in 1978. These sumps were connected to a pipe which carried the pumped water outside of each portal. The pumps were activated by float switches and were subject to continuous service. The sumps effectively dewatered the tunnel until completion of the line change last year. In 1988, crown cuts were made in the tunnel to allow for the passage of double-stacked intermodal trains.

Not only did the sumps installed in 1980 effectively remove the ground water under the invert, but they also removed the fine silts associated with the glacial till deposits. Heavier silts and slurries were mucked out routinely by our Maintenance of Way employees to keep the sumps working. So over the course of 10 years, voids were pumped under the nonreinforced sand and cement invert—causing it to collapse. Fortunately, this was all relatively gradual so that no catastrophic failures occurred, but it created unstable conditions which required spot surfacing 2 and 3 times per week.

Because of the unstable conditions and frequency of spot surfacing, a permanent 25 MPH slow order was placed through the tunnel. Every precaution was taken to ensure the track did not deteriorate to a 10 m.p.h. condition because of the tight fit of the double-stacks in the crown cuts and the inability to take superelevation out of the curve because of the dependency of the superelevation and alignment to match the crown cuts.

In 1990, it became evident that to continue a safe, reliable, and efficient operation over this corridor, the Vista Tunnel had to be dealt with. The following five alternatives were seriously considered as solutions:

First: *replace the existing collapsed sand and cement invert with a new reinforced concrete invert.* It was felt this would be a permanent solution. The new invert would provide the durable and impervious barrier required for a track foundation through the tunnel. It was felt that this work could be accomplished with a minimum of 3 weeks of "dead track" time. Although preliminary estimates showed this alternative as being less expensive than the line change alternative, it was estimated that rerouting traffic for the 3-week period would cost in excess of \$4 million and cause major delay of customers' goods.

Second: *grout and/or backfill voids in the invert.* As mentioned, this had been tried before; but it was felt that a better job could be done with modern equipment and materials. The track and ballast would be removed exposing the deteriorated invert for several days. At the same time, it was known that this was a "band-aid" option because an unreinforced invert bearing on saturated and erodible subgrade would surely fail again.

Third: *construct a small drainage tunnel along the outside and slightly below the south wall to intercept the ground water before it can reach the tunnel and saturate the soils beneath the invert.* The invert would still have to be repaired as suggested in alternative No. 2. The principal advantage of the drain tunnel was that it could be constructed without interfering with rail traffic. Obviously, we would still have a tunnel with close clearances to deal with.

Fourth: *construct line change and bypass Vista Tunnel with an adjacent tunnel providing improved clearances and drainage systems.* It was known that this alternative would avoid some of the environmental concerns and costs associated with open cutting; however, construction costs for a heavily reinforced concrete tunnel in soil was going to be approximately 6 thousand dollars per foot—or 5 million dollars just for the structure.

In the fifth: *two open cut line change alternatives were reviewed*. The first was the same as that proposed in 1958. This 10 thousand foot line change would eliminate a 3 degree curve, bypassing the tunnel on the south side. The estimated cost of this option with an open cut was \$5 million versus \$583 thousand in 1958. Another option—the one chosen—was to make a 3 thousand foot line change and bypass the Vista Tunnel on the north side. This option would not eliminate any curves, but cause a relocation and lengthening of the existing 3 degree curve at the east portal along with the creation of a 2 degree reverse curve to return to existing alignment west of the tunnel. This option was estimated to cost \$3 million and could be accomplished with little or no delay to trains on the corridor. The open cut options were the only options which eliminated clearance concerns for future traffic.

A concern for all the bypass alternatives was how well the existing tunnel would stand up to excavation and construction activities both above and adjacent to it. Shannon & Wilson Engineers felt that with proper excavation steps, coupled with a measurement system to constantly monitor the tunnel for movement, that the work could be performed without causing catastrophic failure.

The proposed cross section incorporated Burlington Northern's typical main line cross section including "V" drainage ditches through the cut. Plans made provisions for a bench having 1-1/2:1 slope to

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provide lateral support and resistance to the tunnel during excavation. The final cut cross section was to have, and does have 2:1 back slopes with the south slope just grazing the tunnel crown on the east end.

A vertical curve was designed into the track profile to raise the top of rail elevation through the cut, 6 feet above that in the tunnel. Although this increased the westbound ascending grade from .25% to .6%, for a short distance, it saved the excavation of an additional 50,000 cubic yards of material and ensured effective ditch gradients through the cut. This track raise also provided more cover over the migrating subsurface water flowing toward Whitefish and Boyle Lakes. The alignment through the cut is a 3 degree curve requiring 2-1/2 inches of superelevation for the posted speeds of P-55/F-50.

Large crushed rock was used to build the embankment east of the cut area. Rock was selected so that a 1-1/2:1 slope could be maintained to avoid the need to acquire land from an adjacent private land owner.

The original proposed alignment was altered slightly so that the only property owner we had to deal with was the State of Montana. Before construction could begin we had to obtain two temporary construction easements and one permanent easement from the Montana Department of State Lands. The three easements totaling 16 acres, were used for project construction and access, a haul road, the staging of equipment, storage of topsoil, hay bales and brush, and for the construction of a temporary dam and filtering system for surface runoff. Along with the easement fees, we paid fees for the tree removal and a 5 cent per cubic yard fee for soil removal. Approximately 60% of the total excavated material came from state-owned land. Approximately 20 acres of the 133 acres purchased in 1966 was used as a site for surplus material disposal.

The environmental issues and concerns were addressed in an efficient and expedient manner. OEA Research, headquartered in Helena, Montana, was brought in during the preliminary designing stages of the project. Being Montana-based, they had many contacts with the various State agencies and because of their past work with these agencies understood the various agencies' viewpoints, concerns, and requirements. OEA Research and S & W orchestrated a series of meetings with state and federal agencies and the public to bring their input into the design process. This approach brought the Montana Fish, Wildlife and Parks, the Montana Department of State Lands, the U.S. Forest Service, the U.S. Fish and Wildlife Service, the Army Corps of Engineers, and special interest groups into the project as co-planners rather than after-the-fact adversaries. We were able to commence construction after a simple, yet thorough environmental checklist versus time consuming and costly environmental impact studies or reviews. The only actual issues we had to deal with were a pair of nesting bald eagles in the area and protection of adjacent wet lands. The bald eagle concern was mitigated by our \$5 thousand funding for eagle study. The wet lands were protected by a slight alignment change and effective control of run-off, erosion and sediments.

After securing capital funding for the project and the eagle chicks having hatched, we began excavation on July 8, 1991. Knowing the work season could possibly end as early as November 1, 1991, Baltrusch Construction Company, from Havre, Montana, commenced work with a fleet of equipment capable of moving the 540,000 cubic yards in a relatively short period of time. The average excavation quantity was 9,812 cubic yards per day. The disposal area was located in relationship with the cut area such that scraper turn times averaged 7.5 minutes and rock wagons made the loop in 6.0 minutes. Excavation and fill placement was completed in 55 days.

The material excavated was cobbly, bouldery glacial till for the first 10-15 feet over clay. The size of the boulders ranged in size from 6 to 8 inches in diameter to 6 foot diameter boulders. This type of material made it next to impossible to use scrapers for removing and transporting some of the top material. Five 13-yard front end loaders were used to load five 40-ton rock wagons in conjunction with the fleet of 7 scrapers. Because of the dry summer and hard material, the entire cut had to be ripped. The average life of a ripper tooth on the job was 1-1/2 days.



Photo 2. East portal of tunnel remains after Vista Tunnel bypass.

We were able to use a haul road over the tunnel for most of the project. This allowed work to continue with no impact on train traffic. However, as excavation approached final grade, it did become necessary to cross the main line east of the tunnel with a second haul road. The haul road adjacent to the track was the widened embankment rock fill which would serve as the grade for the new alignment.

During excavation Shannon & Wilson had measuring devices and gauges installed in the tunnel to monitor movement of both the tunnel and cracks that were present in the lining prior to excavation or that occurred during excavation work. The tunnel experienced racking movement through the excavation period. The rapid increase in movement in mid-September had us concerned and caused the track construction to move at a little faster pace. At the end of the project, total racking was less than 1 inch.

The track was built using BN-100 concrete ties produced by CXT in Spokane, Washington. The rail was 136 pound Nippon head hardened CWR. The west end of the new grade was used as a storage area for track material. The ballast used was a crushed basalt meeting our 2-3/4 inch main line ballast specification. We opted not to construct a temporary turnout to access the line change because of its fairly short length and the availability of material moving equipment.

On October 11, 1991, 95 days after commencing excavation we took 6 hours of available track time and cut both ends of the new line change in. It is an attractive finished product that in a short time will blend in with the beautiful Montana scenery surrounding it. The hydro-seeded back slopes are covered with a jute mesh to protect the slopes until vegetation can start its growth. Light reflectors and refractors are placed at 50 foot intervals, locomotive headlight-high, on the back slopes to frighten deer, moose, elk, and bears as a train approaches the line change cut at night. The 5,000 planted fir and pine seedlings will reforest the disturbed timberland and the naturally undulating landscape placed on the disposal area will appear just as natural as it did before we moved a half million cubic yards of material to solve a chronic operating and maintenance problem. The tunnel will remain in place, but has been filled with large pervious material to keep trespassers out and to reinforce the structure. The tunnel will serve as an interceptor and transporter of the subsurface water which has plagued it for 88 years.



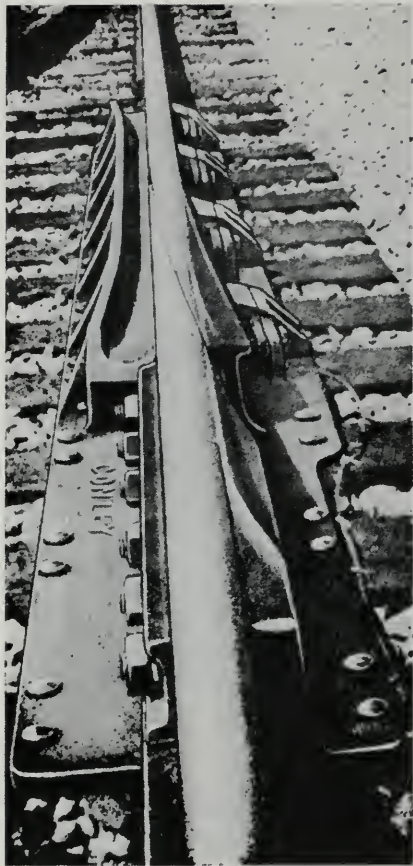
Photo 3. West end of line change looking east toward Vista Tunnel.

This project was completed ahead of schedule and under budget. This accomplishment was solely because we had open lines of communication from the on-start with two excellent consultants. They, in turn, opened lines of productive communication with governmental agencies in a state known for its environmental red tape and dislike for big corporations. At the public hearing we had the various agencies on our side to hear the public's and special interest groups' concerns and to answer questions and make comments in support of the project. This type of understanding and cooperation is something we don't see enough of and does not come by accident.

The key to any successful project—large or small—is planning and communication.

I want to thank the Shannon & Wilson Engineers, Leland Jones, Jerry Milar, Dex McCullough, and Mike Vitale along with Steve Gilbert with OEA Research for helping make the Vista Tunnel Bypass Project a successful project.

On behalf of the Burlington Northern Railroad, thank you for the opportunity to review this project.



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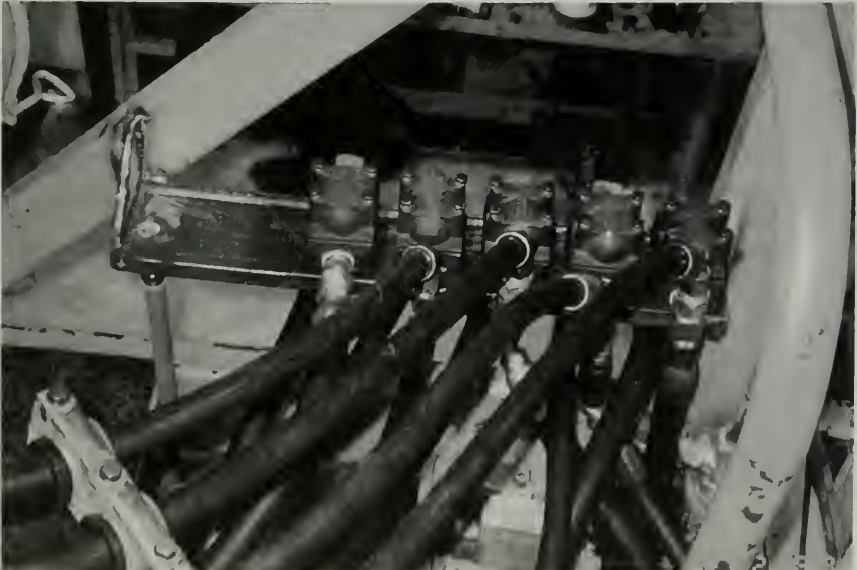
PANEL DISCUSSION ON MAINTENANCE OF WAY EQUIPMENT*

Preventive Maintenance Program

By: Jack L. Condon**

At Burlington Northern there have been many past meetings and discussions concerning what could be done to improve the quality of our fleet of roadway work equipment machines. One of the first concepts that comes to mind is a Preventive Maintenance (PM) program, which was fairly easy to identify the results desired, but extremely hard to implement as it requires integrated detailed steps and procedures to establish.

In 1989 we began to aggressively search for an answer, by meeting with and attending seminars with a variety of preventive maintenance consultants, Caterpillar, etc., that have established good comprehensive systems but did not fit the unique operating parameters and organization typically associated with the railroad industry. A preventive maintenance program will improve the condition of the equipment fleet due to the fleet being inspected and machine condition being evaluated so each machine is properly maintained at prescribed intervals. These intervals will be based on engine hours, and no longer on educated guesses. This procedure will assure that the machine's condition is maintained at an improved and prescribed level. A side benefit will be the monitoring of the actual usage of the machine in terms of engine hours, cycles, insertions, mileage. Like any other preventive maintenance technique it requires an investment at first. However this investment is a modest one in terms of potential contribution to profit through reduced total maintenance cost and increased utilization and/or productivity resulting from reduced down time. More importantly, it requires a company commitment which in the past was often given little more than lip service, particularly outside the maintenance department. Fortunately this year, management has agreed to support our efforts to develop a PM system which at the same time will provide utilization measurements.



Typical example of Schroeder test blocks installed in various hydraulic circuits installed for easy access.

*The panel discussion consisted of an introduction by Vin Terrill, President of REMSA, presentations by Jack Condon, Knox Kershaw, Bob Newman and Charlie McMahon and a question and answer session moderated by Tom Smithberger, AREA Director of Engineering.

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The project consisted of reviewing the PM needs of the entire BN system and subsequently establishing 13 preventive maintenance inspectors and necessary data entry persons. The data entry persons are located at appropriate work equipment locations, and PM inspector locations are based on logical geographic areas with respect to seniority districts to get the widest range of coverage per person. Basic PM starts with the Operators Daily Log Book being accurately maintained, which consists of 2 sections; one for documenting all daily maintenance activity and one for noting all repairs performed to the machine. The system will provide for routine inspection and evaluation of machine condition as well as actual usage of the machine in terms of hours, cycles, and/or insertion count. Such a system, *first* requires vital machine information as well as machine condition exceptions noted, which will be input into the computer data base on a weekly basis. The system would at the same time automatically date stamp the information for future reference and report generation. Resultant computer generated reports would be in the form of PM due for specific machines depending on accumulated hours of service and/or required follow up maintenance. A typical report would list machines that have reached the established service interval for inspection, currently 300 hr. increments.

The actual inspection procedure for each specific machine type is detailed in a 'MACHINE CHECK LIST' book. For each machine there will be 4 color coded books, one for each 300 hr. interval, up to 1200 hrs. at which time the sequence starts over, or there is shop maintenance or complete overhaul. Items examined are: hydraulic pressure and flow performance tests, oil samples on all fluid systems, measurement of tolerances of various working parts of the machine, and inspection of all safety appliances. These machine checklists are prearranged step-by-step inspection points on the machine that must be inspected and analyzed to determine its existing condition. It would also be part of the PM's position to review the operators knowledge and compliance of required daily maintenance requirements on the machine as well as correct operation techniques.

After the inspection has been done, the PM inspector would report back that the machine was completed *only* after all required maintenance, repairs or previously stated machine exceptions are performed. Reports will then be generated which will assist in making more intelligent and cost effective decisions as to when maintenance is actually required. Reports and graphs can be generated which will allow trend analysis reviews for component performance over time. This would include such things as hydraulic pump flow, vibrator motor efficiency (AMPS or VPM) which will allow the equipment management group to shift from one of maintenance by reactive or catastrophic failure to that of predictive and scheduled maintenance. Last year the Nebraska and Dakota Division experimented with independent prototype projects. These helped establish some of the ground work and bench marks for the current system being implemented this year on a system wide basis.

One of the important things that have been implemented that we feel are integral to a successful PM program is oil sampling with particle count. This has led to much effort being given to improved hydraulic filtration as studies have generally shown that 35-40% of breakdowns are related to hydraulic failures. Standard OEM return line filtration of 25 m. vividly displays poor oil cleanliness levels rated by ISO values. When changing to finer filtration such as 7 m. you can see dramatic improvements in oil cleanliness levels. At BN we are striving to achieve a minimum of ISO 15/12 rating at the 5 and 15 micron level. When comparing the contaminant particle size vs. the typical dynamic clearances between hydraulic pumps, motors or valves internal working components, you can quickly see the need for high quality filtration.

The PM data base has been structured to store the oil sample results so trend analysis can be used to determine such things as hydraulic filter effectiveness which relates directly to component service life. Further, trend analysis reviews can be charted for engine, transmission and gear box condition based on oil sample results which indicate the type and concentration of contaminants in the fluid. BN has adopted a standard wherein all power shift transmissions are being equipped with a 'Pall' filter assembly with the green and red condition indicator lamp system. Past records have indicated that of all failed engines returned for system shop overhaul, 33% of those suffered from oil contamination and 15% suffered from overheating.

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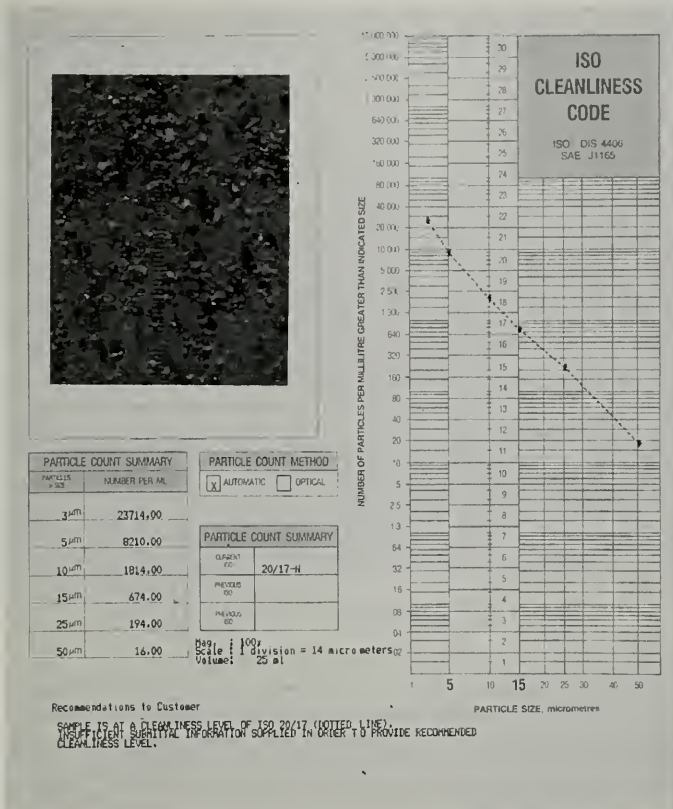
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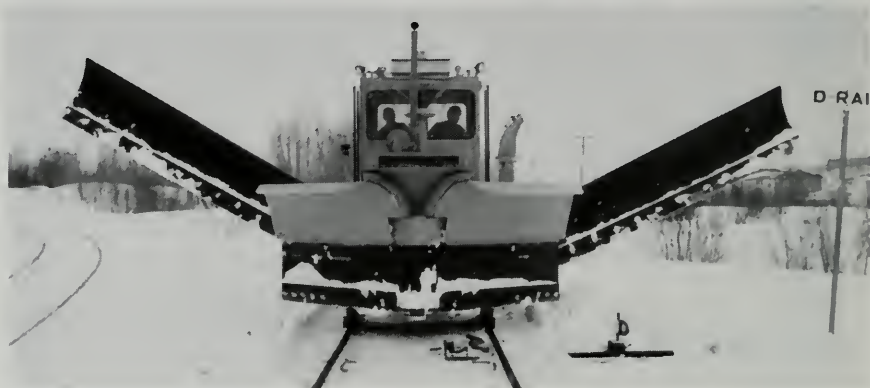
Example of oil analysis report of typical low cost hydraulic filter assemblies using 25 micron elements.

Other filtration improvements BN has standardized on is that of Schroeder return line and high pressure hydraulic filters. These not only improve cleanliness, but protect the hydraulic system from catastrophic pump or motor failure. These filters protect a system from metal particles contaminating the total system resulting in very costly delays due to a complete hydraulic system clean-up being required. Dramatic savings can further be realized with hydrostatic systems, as a failed \$4600 pump will not also destroy a \$4500 hydraulic motor, since it is protected with high pressure filters. Not a bad return on your investment considering element cost is approximately \$20.

Each filter assembly whether return line or high pressure will be provided with a pressure differential switch connected to a red and green indicator lamp in or near the operator's console. A green light will be illuminated until a filter reaches 90% of its maximum flow capacity, at which time the green light will go out and the red light will be illuminated. This provides the operator with precise knowledge of the actual condition of the filter elements. Thus, filter element change-out will occur only when necessary, not prematurely and not too late.



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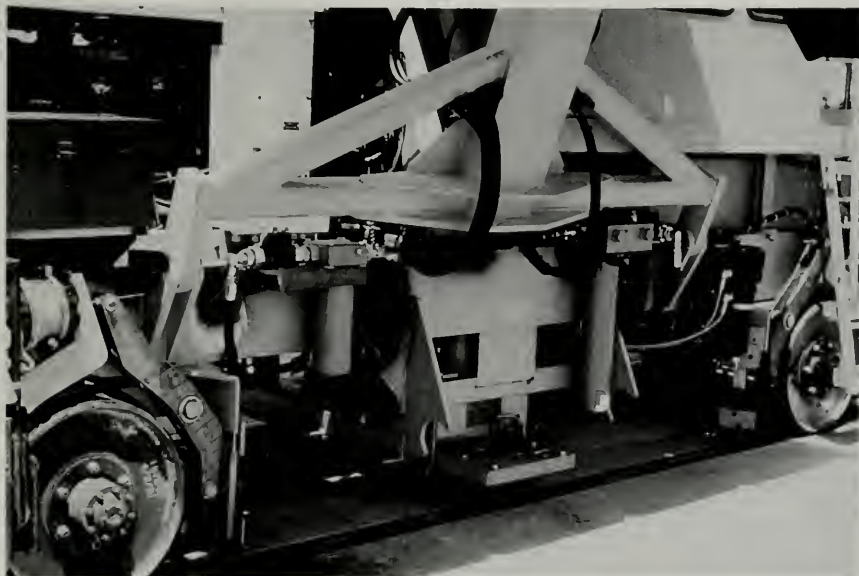


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Typical high pressure hydraulic filtration.

This same technology of monitoring filter element condition is being applied to the diesel engine air filtration assemblies. Here a Donaldson dual element air cleaner system with a pre-cleaner and aspirator is used to provide a very high quality air intake system. In this application a manual locking restriction indicator and electronic pressure switch is used to control a red and green indicator lamp assembly to again continuously monitor the actual condition of the elements in the air cleaner assembly. This allows for element change out only when necessary.

Another standard for hydraulic cleanliness is that of a 3 m. hydraulic reservoir breather to assure that dust ingestion is kept to a minimum. And yet another standard on BN machines is that of a dual element pre-filter system to assure all makeup oil added to the hydraulic reservoir is pre-filtered through a non-bypassing dual element 10 m. filter assembly. The reservoir is also set up to eliminate the age old process of adding dirty oil to the system without it first being filtered. With these practices, not only are all hydraulic component lives extended but so is the life of the hydraulic fluid. This is extremely important in view of the current EPA considerations for proper handling and disposal of these fluids.

Another area BN is aggressively pursuing is that of expanding its fleet of service maintenance lube trucks. These are 32,000 GVW and have reservoirs for dispensing necessary types of oils, lubricants and greases to maintain a fleet of work equipment machines. They have been set up to quickly evacuate machine engine oil reservoirs into a waste oil reservoir via quick disconnect couplings which have been installed on the machines. An oil drain filter rack has also been provided to achieve complete oil draining of filters prior to disposal.



Service maintenance lube truck. Completely self contained for dispensing fluids and greases, and contains a pressure washer to clean equipment.

High wear technology is another area we have invested a large amount of time and effort in, which also relates to preventive maintenance and service life extension. This concept has applications into a multitude of areas such as tamping blades, ballast regulator plow blades, skids, ballast deflectors, switch and crossing undercutter parts, and various other high wear items. These items, as can be guessed, cost more initially but all studies to date indicate that it is by far the most economical alternative. Our records indicate the actual cost is generally 3 to 4 times the OEM price and service life is anywhere from 5 to 10 times greater. These comparisons do not even consider the potential savings from personal injuries associated with more frequent component change-outs as would be experienced with standard wear parts.

With the implementation of a comprehensive PM program, the BN Work Equipment Department is nearing one of its major goals of becoming an equipment management group in the true sense of the words.

Leases and Contracts

By: Knox Kershaw*

In the brief time allotted to me to discuss issues relating to leases and contracts between railroads and outside suppliers, I have only enough time to touch briefly on a few issues. By far the most important is Indemnities. But first, a little background.

My company has been in the business of leasing and contracting railroad track maintenance equipment since the early 1960's. To give you a sense of the type of work covered by our lease/contract agreements and our competitors, I would like to share with you the following:

- Our super hi-production Shoulder Ballast Cleaner—Typically, our contract provides that we furnish all of the operators and expendables. We are paid a daily rate with an incentive based on footage.
- Our 15 yard cleaners—With this service we can supply the *machine only*, or with one operator as a partial service contract, or with two operators as a full service contract.
- Our Plasser undercutter—In addition we contract 2 Kershaw Undercutters. With undercutters we supply 3 to 5 men plus all parts and expendables. Also, we have a switch undercutter in our fleet.
- A Ballast Regulator which we have remanufactured—We can upgrade these machines in the remanufacturing process. Usually we contract for this work on a time and material basis with an estimate. A new machine warranty is part of the contract.

Insofar as the contract document is concerned, it usually takes about one page of what is sometimes a 20-30 page document to describe the actual work that is to be performed. All of the remainder of the contract deals with legal issues. A list of these issues would include, but not be necessarily limited to the following:

1. Insurance—General liability—we are usually asked to furnish a certificate of insurance. Sometimes we are asked to waive the right of subrogation.
2. Responsibilities for contractor equipment and railroad's track and equipment,
3. Fiber optic cables,
4. Personal injuries—railroad employees, contractor employees and third parties,
5. FELA,
6. Sales and Use Taxes,
7. Environmental and hazardous chemicals;
8. And last and most important, the issue which touches all of the preceeding, *Indemnification*.

All of our contacts with the railroad to market our services are through the Engineering Departments. Only after the job is let for bid do we become involved with the legal terminology of the contract, and as a result, sometimes the legal department of the railroad. In the past we furnished a standard contract which was fair to both parties. Now we find increasingly that our contract is unacceptable by some railroads, and a contract prepared by the railroad is forced on us on a "take it or leave it" basis. These contracts seem to have as their goal to indemnify the railroad from every eventuality regardless of whose negligence was the cause of an accident. In other words, railroads are trying to transfer all of their risk exposure in the contract by making unreasonable and unfair demands for indemnification.

How does this affect the contractor? This depends on who you are. All of you in the audience have noticed particularly over the past ten years the continuing trend toward a concentration of the supply industry. Many firms have gone out of business. Through merger or acquisition the smaller firms have gradually been absorbed into larger firms. Two examples would be Fairmont/Tamper/RMC/RTW or

*President and CEO, Knox Kershaw Inc.



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Pandrol/Jackson/Speno/Dapco/McKay. Certainly the contraction of the market has had an effect, but competition remains in a state of decline. In many cases where there were four or even five maintenance of way machine manufacturers or contractors who could possibly supply a specific machine or service, now there may be only one, two, or, possibly three. While the majority of the companies in the railroad supply industry are not parts of larger companies, I am beginning to find myself as an owner/manager in a small minority.

Knox Kershaw, Inc. is a 5-7 million dollar revenue company with approximately 60 employees. My insurance bill is over \$250,000. per year. We have one competitor who does about 25 million dollars of business. The rest of my competitors are all business units with individual sales of \$50 to over \$100 million that are small parts of large financial empires with hundreds of millions of dollars of capitalization. Not only can they get a better deal on insurance, but they can afford to be self-insured. When an onerous contract is presented to them they can simply turn it down. When such a contract is presented to us, and we find that in order to make an annual profit we must have the work, we have few choices. It may well be that with one or two unfortunate incidents, which are not our fault, I would be forced to liquidate my business. My competitors would not since they can afford it. The railroad would not since the majority of railroad companies we deal with are billion dollar companies. It is not only a question of what is fair but also a question of whether you want to maintain and foster a strong competitive market. Railroads should keep in mind that the more hard-nosed they are in enforcing indemnification clauses, the more likely they are to eliminate competition.

We are constantly asked to indemnify the railroad for claims that are uninsurable. For example, FELA claims are not insurable. My employees are covered under worker's compensation. The railroad's employees are covered under FELA. We cannot buy insurance for railroad employees covered under FELA. The railroads seem to be trying to put us in an unfair position where if one of your employees caused an accident, a claim could be passed through to us that would simply put us out of business. Common sense is that the railroads should be responsible for their people and we should be responsible for ours. If there is an accident, each party should be responsible for their contributory negligence. Railroads continually seek to be responsible for only their sole negligence which is simply unreasonable and not at all a fair balance. There is a contradiction when a contractor is asked to furnish a certificate of insurance and then offered a contract which may be uninsurable.

My sense is that the railroad's motivation for these contracts is the fear of going to court, whereas a railroad may not obtain a fair result. In this case would specifying arbitration for contract disputes be a viable alternative?

States are on the warpath to collect sales and use taxes. These taxes cannot easily be taken into consideration in the bidding process since they vary widely from state to state, and some railroads do not always inform us of the states we will be working in until they tell us where to ship the machine. Therefore, they should agree to pay these taxes. (For those of you from the supply industry in the audience, we recently won a lengthy legal battle in Kentucky on this issue and would be happy to share the results with you).

In summary, I hope you will take the following message back to your legal departments and to your management as appropriate. Modifications are going to have to be made to the unreasonable contract demands or you will find that there will be fewer and fewer people who are willing to do business with you. And one day you will find that it will be solely on their terms.

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Equipment Innovation

By: G. Robert Newman*

First of all I wish to thank AREA for the opportunity to speak at this conference about new technology in the track machinery business. Since most of you would naturally associate me with Fairmont, I would like to indicate that I will address this subject as generally as possible for the track machinery supplier industry.

In order to give you a ten minute overview of what is new in this business, I would like to approach the subject by explaining how we determine what to develop, and then in turn, that will give you insight into what is coming for the future.

New development is driven by two basic forces. The first is customer driven requirements for new and improved machines, and the second is technology driven developments. Technology driven developments result from a new technology that we may develop in-house or from developments by industrial component or material suppliers. Two examples of customer driven new product developments are quick removal equipment for Burlington Northern and the curve gang spike driver for Union Pacific. The customer driven requirements for the quick removal tie equipment were:

- Less track and more train traffic creates the need.
- Exit the track under most conditions.
- Use track more for trains than for track maintenance.
- Production rates of 120 ties per hour per gang.

Photo 1 is a picture of the tractor removing and inserting ties. The tractor is also designed so that it can remove the other equipment from the track and then exit the track.



Photo 1. Tractor of BN quick removal equipment.

*President, Fairmont Railway Motors

A second example of a customer driven development is the curve gang spike driver for Union Pacific. In this case Union Pacific asked Fairmont if we could develop a small, light weight, high production, automatic feed, and two man operation spike driver to replace their former standard air hammer system. Photo 2 is a picture of the machine developed which resulted in work force reduction and improved safety.



Photo 2. UP's curve gang spiker.

Now, I would like to give you some examples of technology driven new product developments. For the first case the technology came from within our own company which is commonly the case for Fairmont and other track machinery manufacturers. Inside technology most often comes from sales and service or from our engineering staff. In this particular case the technology came from our engineering department and the project is a new generation tie inserter remover called the TKO II. The advantages of this machine are in the areas of material handling and safety.

Next, I would like to give you some examples of technology driven new product development where the technology comes from an outside source rather than internally. One key area of outside technology is in electrohydraulics. Electrohydraulics is the combination of electronics and hydraulics. One example is new position displacement transducers that are now available. Schematically, Photo 3 shows how what is known as a string pot works. In the case of a string pot, large displacements can be measured accurately. Fairmont and other suppliers are using these to great advantage on new equipment.

Another example of externally driven technology is electrohydraulic proportional valves. Here we can combine the analog output of an operator controlled joystick and the digital output of a computer to sequence and control new machines. This arrangement results in precise and fast control of new equipment that was not feasible just a few years ago. In Photo 4 we see the Vickers proportional valve, a joystick controller, digital computer, and a digital motion controller or DMC. The DMC takes analog output from the joystick and digital information from the computer and changes this to a pulse width modulate signal or current.

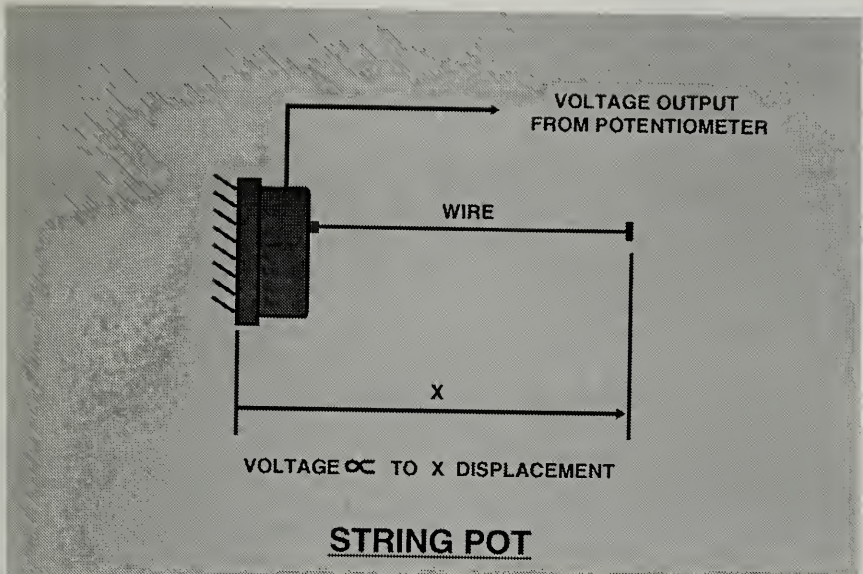


Photo 3. String pot schematic.

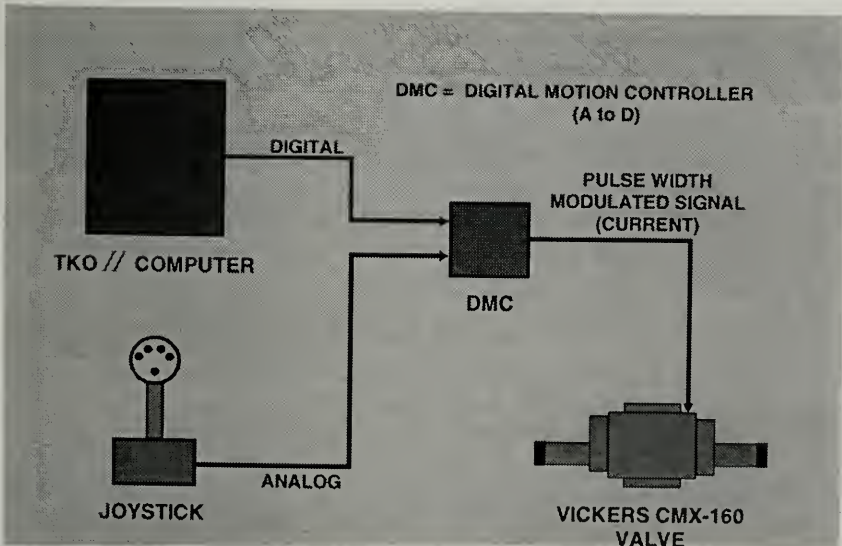
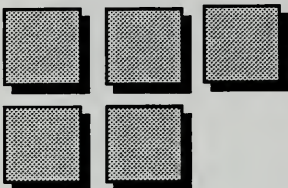


Photo 4. Electrohydraulic proportional valves.

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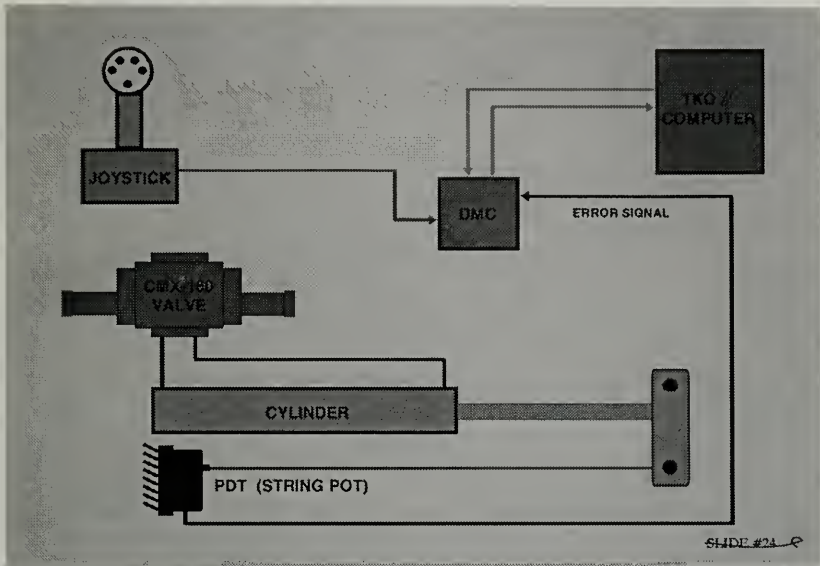


Photo 5. TKO II control system schematic.

On the experimental TKO II development of the control system was a major challenge. The system was required to combine multiple automatic sequences with precise manual control of two large telescopic booms. In addition, the system had to have numerous manual override functions and provision for a large amount of safety control. Obviously, a control system of this type requires a digital computer. To control the large displacement booms, the computer must have a precise feedback system as shown in Photo 5 where you can see that we are using the previously described string pot as a feedback system to tell the computer exactly where the booms are at any point in time.

In summary, I would like to say that the availability of modern electrohydraulics is making more automated and efficient track machinery feasible today than was possible just two or three years ago.



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Equipment Diagnostics

By: Charles G. McMahon*

When a mechanized production unit is given track time for maintenance it's machinery must function with the most uptime possible. The machines work up to potential, however, the railroad environment is very harsh on complex electronics. Machines can and will break down, therefore, it is imperative that machine defects be diagnosed and repaired as quickly as possible.

Track maintenance and program work becomes more mechanized each year. Track time allowed for maintenance of way work has been reduced due to improved traffic schedules such as just-in time, guaranteed delivery, etc.

Most of M of W machinery and related construction machinery has become very complex. More often than not controls are solid state integrated circuit boards, with extensive wiring running throughout the machine. Therefore, electrical and electronic repair problems seem to present the greatest diagnostic challenge for railroad repairmen. By diagnose I mean ascertain or define the problem. Electronic technology presently exists which can increase both the reliability and fault finding capability on machinery in a user-friendly fashion.

Conrail and G.E.C. Aerospace are currently field testing an intelligent power control system (IPCS) formerly designed for use on aircraft, ships and military vehicles. Our initial experience has been very favorable. We have found several features within the system that have proven very advantageous. The

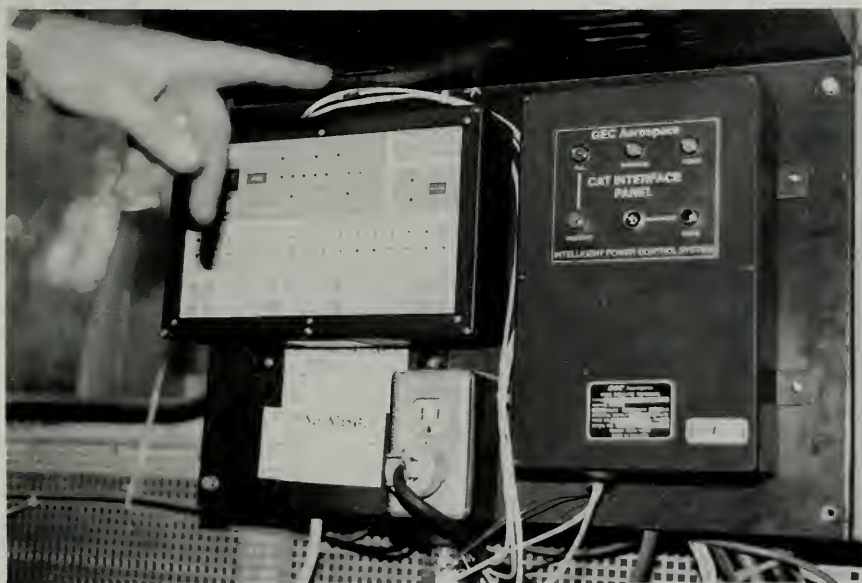


Photo 1. Cab mounted multifunction control and monitor unit (left) and interface unit with fault indicators (right). Entire system operates from standard machine supplied DC voltage.

machine operators and repairmen have also found this system a valuable diagnostic tool and quite easy to use. Without IPCS, a machine could arrive at a work site with an undetected operational fault. With IPCS the system performs a diagnostic test upon start up. We find this an important feature because a system fault could be corrected while the machine awaits track time on a siding. This self test could be compared to the self-test that a personal computer performs at power up.

*Superintendent Maintenance of Way Equipment, Conrail

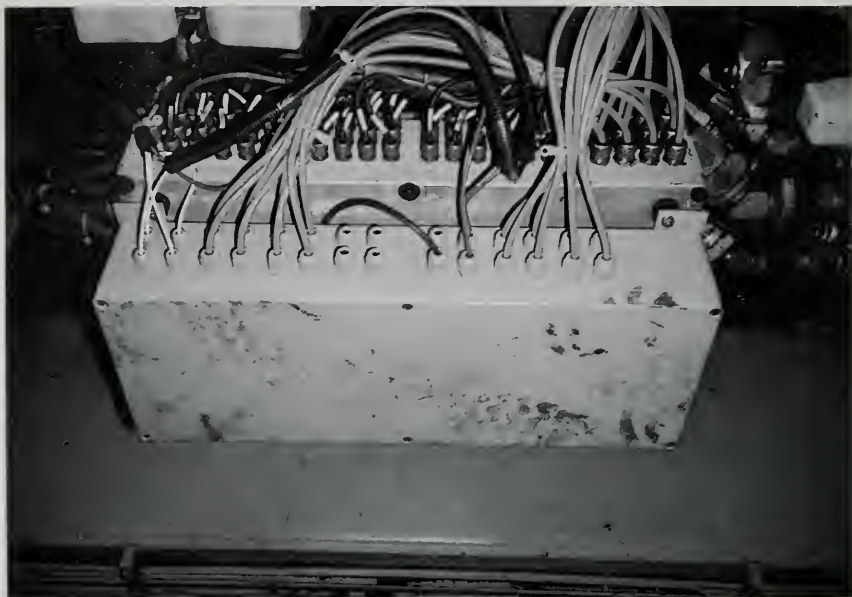


Photo 2. Field installation of remote terminal enclosure utilizing "piggyback" mounting on existing junction box.

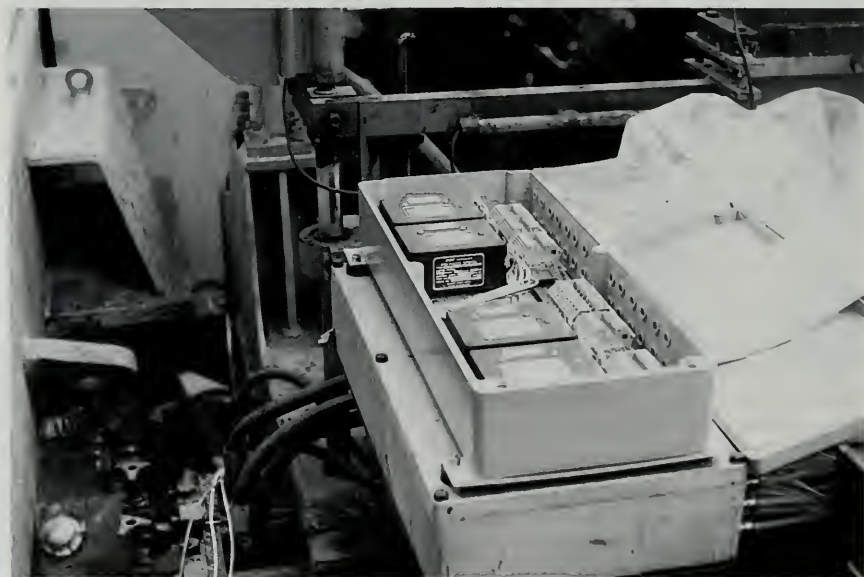


Photo 3. Four remote terminals in separate sealed enclosures (black boxes) provide a combined total of 16 isolated outputs.

During machine operation, the system constantly interrogates for faults. The system is presently programmed to detect 114 faults which are displayed on the control panel monitor for the operator or mechanic. These codes are referenced in the User Manual and are similar to what the automotive industry currently uses.

The Interface Unit has three visual status indications and an audio alarm.

- A. Green: Indicates that the system is good so normal operation starts.
- B. Amber: Indicates a fault has been detected, but built-in redundancy permits normal system operation.
- C. Red: Indicates a fault has been detected which may partially or fully prevent system operation. At this time, an audio alarm will also sound.

If a fault is detected in addition to the interface panel alert, the coded fault is logged in Non-Volatile memory, which is especially valuable in locating intermittent faults. The number of faults is also logged. Some examples of typical faults would be: Short Circuit, Open Circuit and Buss Failure.

The system has two industrial control units (ICU). One is the main unit and the other is a standby. If a fault occurs at the ICU or in its redundant wiring the system will automatically switch to standby circuitry and log the appropriate fault code in the memory. Installation of this system was accomplished in the field without any interruption in machine production. This demonstrates how easy it can be to interface this system to existing circuitry.

The machine's increased dependability has been a direct result of several factors: First, the elimination of 21 electro-mechanical relays. This has also reduced inventory and maintenance costs. Also, it has eliminated 21 wires. These wires have been replaced by 5 wires which provides quadruple redundancy. Finally, it has eliminated 11 fuses. The system is self protected and if an overload occurs a fault code is generated and logged. The overload protection automatically resets when the overload is removed.

The IPCS system eliminates the necessity for suppression diode protection. It also increases coil life due to the soft start characteristics of the controlling activators. In conclusion, the IPCS pilot has the potential to increase uptime in three major areas: (1) it increases reliability by precluding the failure of electro-mechanical relays; (2) it detects faults which are then diagnosed and located rapidly; and (3) it increases dependability by utilizing semi-conduction devices, redundancy and isolation from peripherals. We are very pleased with the results of our initial testing phase and anticipating continued success.

Panel Question and Answer Session (abridged)

Question from Roger Silbaugh, CSX Transportation:

Would something like Power by the Hour work in maintenance of way?

Answer by Knox Kershaw:

Yes, it could work but the equipment operator would have to know everything about their equipment.

Statement from Vinay Mudholkar, Springfield Terminal:

The railroad engineering departments should lead the way in standardizing contracts and follow the architect's lead. They established standards which are standard to all contractors.

Question by Tom Smithberger, AREA:

Could more equipment component parts be standardized, perhaps through AREA Committee 27 which now permits supplier membership?

Answer by Bob Newman:

Certain things already are standardized such as test boards, hydraulic pressures and brakes. Additional work could be done in this area in cooperation with railroaders and other suppliers.

Statement by Don Turney, Norfolk Southern:

We need videos from suppliers for training and maintenance repair.

Answer by Bob Newman:

We can do it but it is time and money.

Statement from Tom Smithberger, AREA:

Ergonomics needs to become more of a consideration in machine design. Not only should the ergonomics of the operator be looked at, but also that of the equipment repairman. One example described by Committee 27 Chairman Jack Hannaford was the difficulty of changing in the field a battery weighing 60-65 lbs. on a machine where the battery is located in a vertical case at a hard to reach location.

Question to Jack Condon, Burlington Northern:

What benefits have you seen with your Preventive Maintenance System?

Answer by Jack Condon:

Mostly from time management. We manage the fleet instead of the fleet managing us. We've had up to \$70,000 in savings. In one case, we went 768 hours without an air cleaner change. Let the monitor tell you when to change the filter.

Statement from Stan McLaughlin, Union Pacific to suppliers regarding Knox Kershaw's presentation:

If you have alternatives to the contracts, give them to us up front, with the additional costs or the cost savings from those alternatives.

CP RAIL'S TRACK MAINTENANCE ADVISORY SYSTEM

By: M. D. Roney*

Serious times like these call for some big changes in the way we look at track maintenance. On the CP Rail System, a 20,000 mile rail network that now covers much of the northern half of North America, there are many ways to spend money. Some of these have pretty direct effects on our business. Track condition does not—until it is too late.

So we have had to take a longer range view of track maintenance planning. We no longer have the luxury of being conservative when we decide to do a track program. We have to be right. We have to know the right place and the right time to replace rails or ties or to surface track if we are serious about winning back business from trucks who don't have to maintain their own infrastructure. And we have to talk to our senior management in terms that a businessman can understand. We have to talk about dollars saved for each track dollar spent.

Our field personnel understand the value of good track, and by and large make good decisions on maintenance priorities. But these decisions should be backed up with the best data the company can muster and must be related to consistent standards and analytical techniques if we are to get the best "bang for our buck."

At CP Rail System, decisions on rail renewal, grinding and surfacing are now assisted with a system we call the Track Maintenance Advisory System. This paper will examine what TMAS is, why we need it, and how it is making us reconsider how we maintain track.

The story started back in 1984 in AREA Committee 32. Our contacts with other railways in this committee had convinced us that there were many potential planning uses of track geometry car data that had not been tapped. By the time that AREA Committee 2 had been formed to deal with the whole area of track measurements, it had become apparent that new track measurements were on the horizon which could make it feasible to talk in terms of objective assessment of a significant portion of track needs.

The concept of computer-assisted maintenance planning was pushed forward by tightening competitive forces. We needed better ranking of our priorities, and we needed to base this ranking on more objective data, as opposed to subjective judgment.

When we presented the concept of direct advice on work priorities to our Division Engineers, we met with widespread support for a system that would put far more data in front of them, while remaining flexible in handling human inputs to the programs. We also learned that the System should reflect as much as possible the current decision-making environment.

Why do we need computer-assisted maintenance planning? Well this became clear to us when CP Rail was reorganized into two Business Units (Figure 1). With the shifting of more of the maintenance planning to the Unit level, it became critical that we be able to compare our large territories against consistent track condition standards.

*Manager Track Technology, CP Rail



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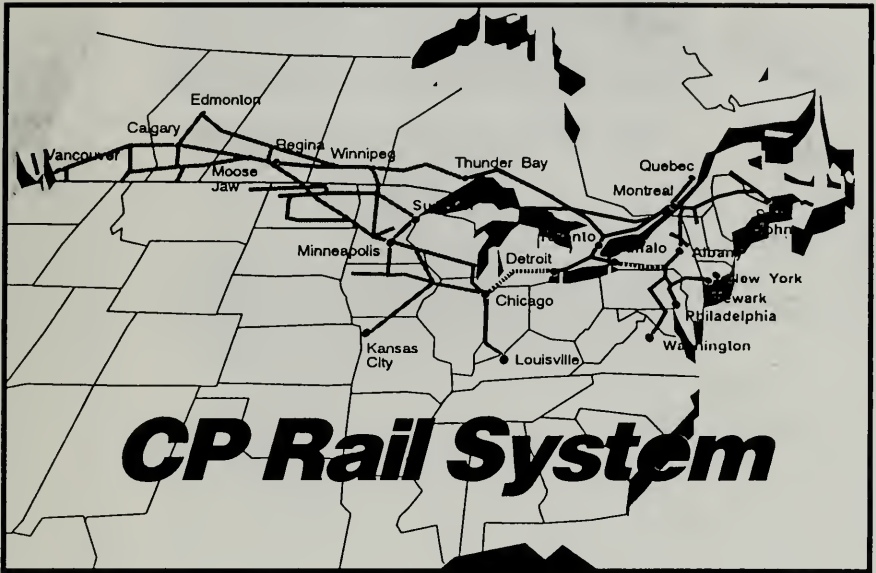


Figure 1. Map of CP Rail System

The foundation of the system are our track condition measurements, or indicators. The development of the Track Maintenance Advisory System started in 1985 with the commencement of a long term program to develop reliable automated track measurements geared to the need for our Track Evaluation Car (Figure 2), which is run up to four times per year over our mainlines. In addition to measuring all of the traditional track geometry parameters, the Track Evaluation Car measures rail wear, rail corrugation, and rail head profile in both the transverse and longitudinal plane.



Figure 2. CP Rail's Track Evaluation Car

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Its sister is our original 1971 vintage Track Geometry Car, recently upgraded to modern standards, which contributes measurement of important branchlines. The Track Geometry Car is also outfitted with a prototype system for measuring track modulus or stiffness which we hope will unlock some clues for ballasting needs.

So what does TMAS do?

Well, it is a system for converting a whole lot of track measurements into 20 Track Quality Indices that are related to our need to maintain track. Each Track Quality Index is projected forward into the future for each for our 70,000 track segments using track deterioration equations, or "models," that we have observed from past track performance (Figure 3). A track segment is defined as a whole curve or 500' of tangent track. If the system determines that a Track Quality Index will exceed a maintenance "trigger threshold," within our 5-year planning horizon, it will trigger a recommended maintenance action. After field verification, these individual segments can then be grouped into logical programs.

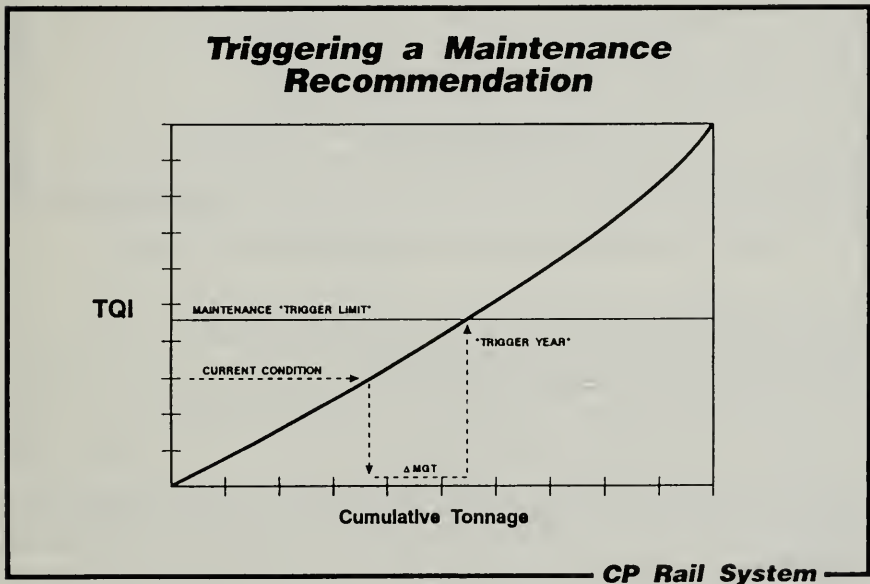


Figure 3.

The Track Maintenance Advisory System is divided into 5 separate modules—one each for the planning of rail renewal, rail grinding, surfacing, ballast and tie renewal (Figure 4). Parallel development of these 5 modules commenced in 1986. The rail module was operational in 1989. Grinding and surfacing modules were implemented earlier this year on our Business Units. The ballasting module will be in place later this year. Tie planning continues to be an elusive target due to our pressing need for more objective assessment techniques for ties, however we are now confident of implementation next year.

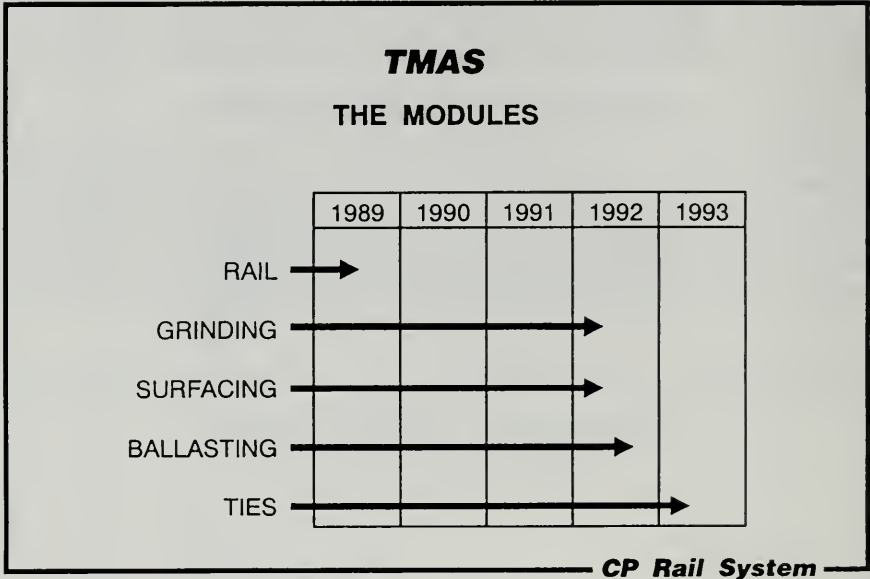


Figure 4. Track Maintenance Advisory System Implementation Schedule

Each of the modules is structured with the same basic elements. These are:

- A method of dividing track into homogeneous segments
- calculation of relevant Track Quality Indices
- track deterioration equations or models used to predict future track condition
- track class or service-based maintenance “trigger limits”
- estimates of the effectiveness of different maintenance actions

In addition, ongoing work is attempting to relate different levels of Track Quality Indices to the costs of fuel, slow orders, life cycle costs of different track components and repairs to rolling stock.

Rail Planning

Rail renewal was our first target area. This is because it is the largest single component of track maintenance expense. Because we are an aggressive grinding railway, head loss is the most important reason for replacing our rail.

This made it pretty logical to install Tamper’s LITESLICE optical rail wear measurement system on our Track Evaluation Car. LITESLICE gives us a measurement of rail vertical wear at the centreline, gauge face wear, total loss of rail width, and the size of both gauge and field size lips every 20’ along the rail. In addition, we taught the system to automatically identify the original rail weight and whether it has been transposed. CP’s Rail Wear Index is defined as the 90th percentile measurement of the percent of theoretical joint bar limits that have been used up in a given curve as a result of combined vertical and gauge face wear (Figure 5).

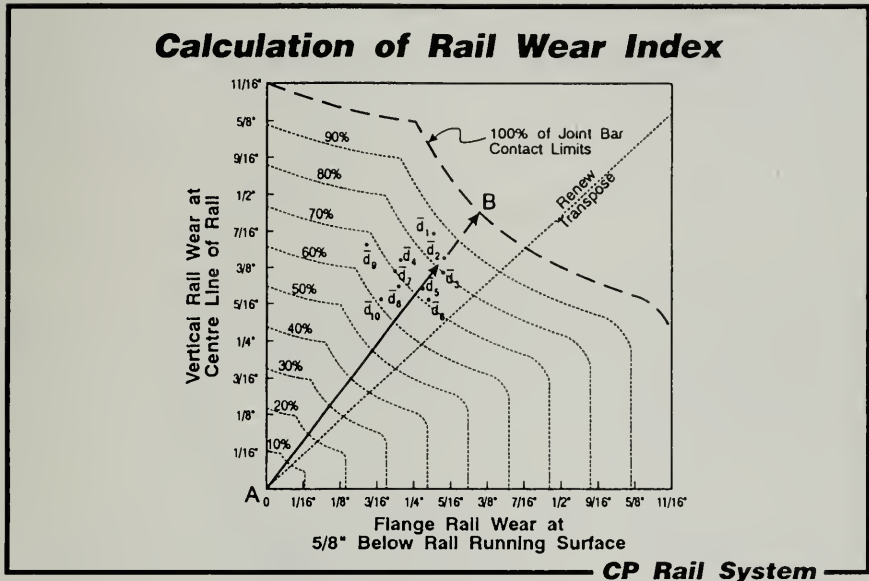


Figure 5. Calculation of Rail Wear Index

We also keep track of rail defects detected by Sperry or Dapco rail flaw detector cars. These are input into the Track Maintenance Advisory System along with service failures. We now have a computer program developed with Zeta-Tech that can project fatigue lives for each track segment based upon fitting defect occurrences to Weibull curves.

Rail Grinding

At CP Rail most track miles are ground to remove surface fatigue cracks before they progress to head checks, spalling or rail shells. The second greatest reason to grind is to produce a shape that is conformal with the wheel while avoiding high stress contact with the "false flange" of the wheel or with the gauge corner of the rail. The third most common reason for grinding is to control rail corrugations.

The TMAS Rail Grinding Module was developed in conjunction with Pandrol Jackson to directly translate automated measurement of rail corrugations, rail head radius and rail crown slope into recommended numbers of grinding passes, pattern numbers and grinding speeds. We currently contract for the Pandrol Jackson Corrugation Analyzer Car, which is run twice a year over mainline track, in advance of rail grinding. The RA-204 provides the data on rail corrugations, rail head radius, and rail crown slope.

As we further develop a "maintenance" or "preventive" approach to rail grinding we will also further refine our assessment of the rail profile shape. This has required the replacement this fall of the LITESLICE system with a high accuracy measurement system called LASERAIL. Using LASERAIL and a new laser-based rail corrugation measurement system (Figure 6), CP is now phasing in the development of grinding production plans directly from the Track Evaluation Car's measurements.

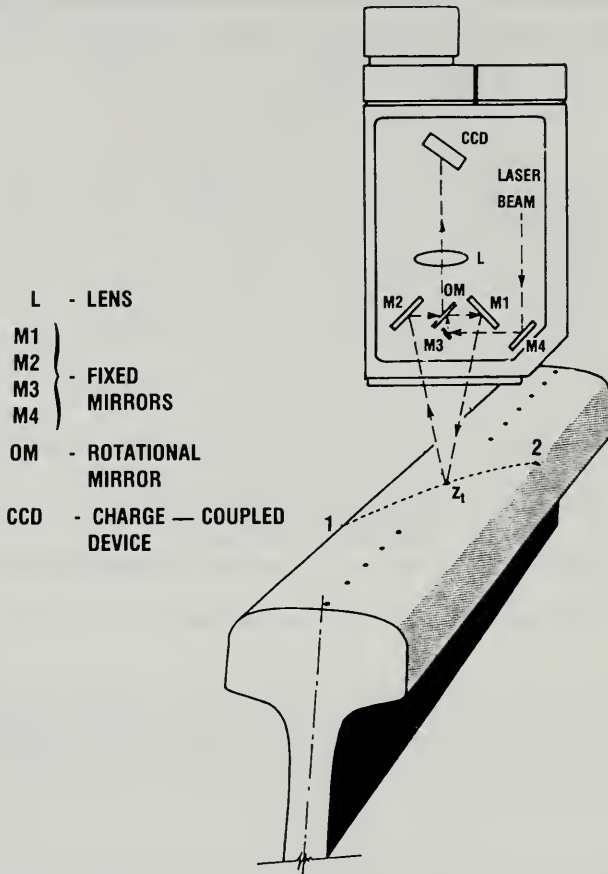


Figure 6. Schematic of Rail Longitudinal Profile Measurement by Laser Camera

We are also working now with our rail testing contractors to see if it is feasible to detect surface fatigue conditions in the top surface of the rail as well from ultrasonic or induction signals. We have experimented with running a Sperry car in between rail grinding passes and are now pretty sure that rail flaw detector cars can be taught to recognize and report on the type of rail surface fatigue that can prematurely terminate rail life if we don't relieve the situation by grinding.

So to recap, our key measurements of rail condition which feed the TMAS modules guiding rail renewal and rail grinding are:

- | | |
|---------------------------|-------------------------|
| —rail vertical wear | —rail corrugation index |
| —rail gauge face wear | —rail head radius |
| —total width of rail head | —rail crown slope |
| —rail defects/mi./yr. | |

and—on the horizon, rail surface fatigue and rail surface profile.

Track Surfacing

Within the TMAS surfacing module, surfacing priorities are developed from track geometry car data. These are rated on the basis of some combination of the sum of squares of deviations in:

- track surface or vertical profile
- track crosslevel
- lateral alignment

or on the basis of curve geometry problems such as rapid rate of change of superelevation (twist) or inadequate curve designs speeds.

Track geometry measurements are stored at 5 foot intervals and then processed as Track Quality Indices for each data channel. Our Track locations, which they take into the field for on-site verification. The Divisions may request other priority locations which did not show up as a TMAS recommendation. In these cases, the Business unit engineering staff would visit the site to determine whether the site needs work for reasons that were not identified by current Track Quality Indices or their projections.

When final plans are reviewed by the Chief Engineer's Office, they are again compared with TMAS predictions run in our Montreal office.

The TMAS system therefore performs the following functions:

1. Display of Track Quality Indices and standards
2. Identification of non-complying track sections by program year
3. Enables "what-if" analyses of work program scope and location vs. different track standards, program combination rules, deterioration rates or traffic levels.

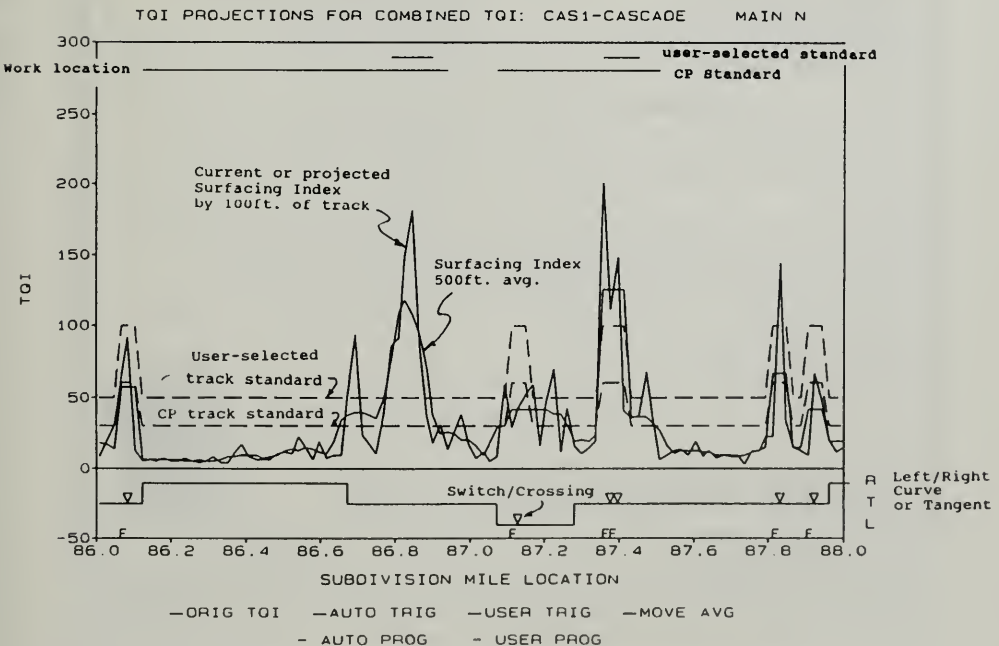
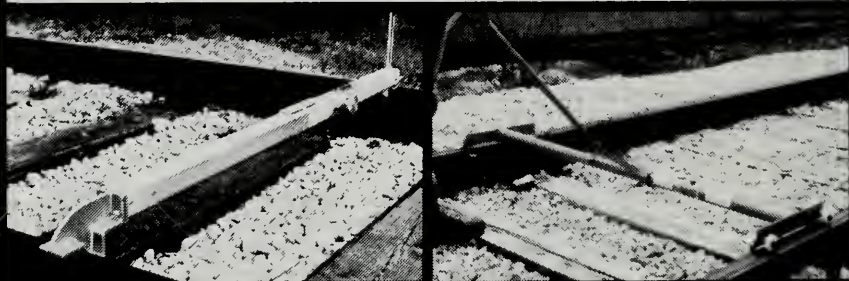


Figure 7. Sample Screen Display from Surfacing Module

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Sample Program Display from Surfacing Module

The process of developing a work program is well illustrated with our Surfacing Module. Figure 7 is an actual screen dump of the color computer screen presented to the maintenance planner as a starting point for computer-assisted planning.

The user first specifies the weighting of each Track Quality Index that the computer will use to define an overall Surfacing Index which will trigger surfacing locations. For example, the index may be the result of adding together 60% of the Surface (vertical) Roughness Rating with 20% of the Crosslevel Index and 20% of the Alignment Index.

The computer then calculates this Index for every 100 ft. of track, displaying spikes which represent local track roughness. These 100 ft. calculations are then averaged for every 500 ft. of track, the larger unit being more meaningful for development of a practical program. The Surfacing Index at these locations can then be projected forward from the date of measurement to the current date or to a date one year in the future. The system performs the projection by referring to deterioration curves for each composite index that are based upon historical observations for each track type.

The current or projected Surfacing Index is then compared to CP's standard for the class of track and individual locations for surfacing are flagged. If there is less than 1000 ft. between two locations requiring surfacing, or if contiguous track locations are within 75% of the trigger limit, they will automatically be added to the recommended program. The TMAS system then calculates the length of the program, the number of individual locations to be surfaced, and generates an expected cost.

To generate a practical program, which may also include locations selected by the Roadmaster, the maintenance planner can use a "mouse" to combine locations or to add new locations directly on the screen. These will show up in the final reports.

Quality Indices are the sums of squares of deviations from design geometry. This calculation automatically weights larger track errors heavily. In fact, any Roadmaster who regularly looks at his Brush Charts or the Track Quality Comparison Graphs he receives has a pretty good idea as to what the Track Maintenance Advisory System will recommend as a Surfacing program.

The weighting of each of the above TQI's in the combined index used to trigger a surfacing program are left to the maintenance planner on the Business Unit, who is aware of the specific concerns related to his predominant traffic types.

Later this year, we will be using the rate of change of these measurements from run to run of the Evaluation Car to differentiate between track which can be economically brought within standards through surfacing and track which requires rebalasting in lieu of frequent surfacing.

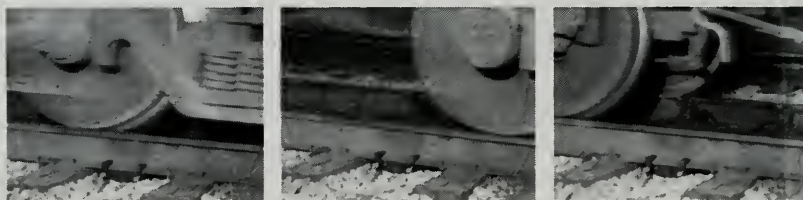
Tie Planning

Our tie module is still under development, but our basic concept is to use bad tie counts from the field as our most important planning data, as in the past. The difference is that we will require at least one additional corroborative measurement to back up a bad tie count that exceeds our trigger limits.

In tangent track we will compare bad tie counts with our Crosslevel Index. In curves, we will benefit from the fact that we measure gauge and rail wear on the same Track Evaluation Car. In a curve, subtraction of lateral wear from dynamic wide gauge is a good indicator of lateral support provided by ties.

We will also be using the AAR's TIERENEW model, which has been calibrated to provide a good estimate of standard tie lives as a function of many different variables. The AAR's model will be input with historical tie replacement levels, traffic levels, curvature, tie type and environmental zone. The result will be an estimated bad tie count, which can both back up the field count, and provide the basis for projecting it into the future.

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One of our remaining objectives is to include a more direct assessment of tie strength. We have experimented with measurement of the angle of rail rollover under load as a proxy for weak tie support in curves. Rail rollover is available from the LASERAIL system, but the measurement suffers the same problem as the wide gauge net of rail wear in that it is only accurate in curves, where the ties are loaded laterally by the Geometry Car.

Using the Track Maintenance Advisory System

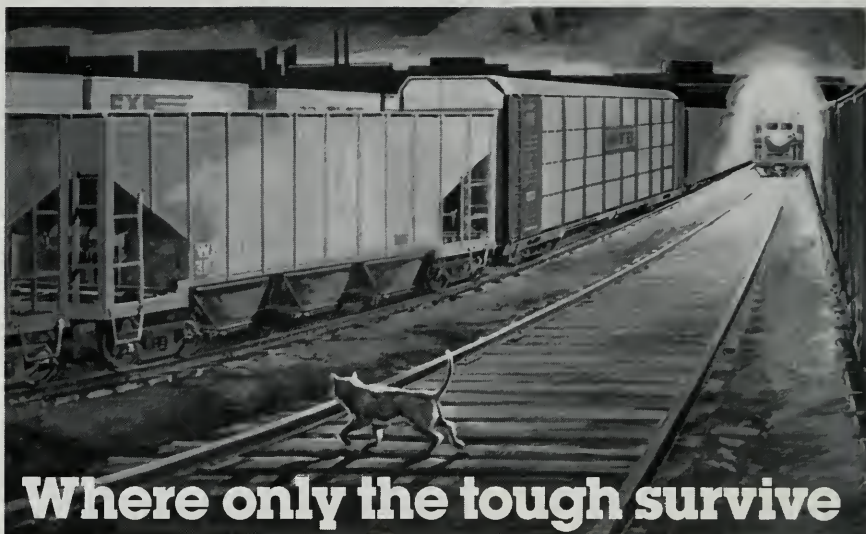
At CP Rail, the planning of major gang activities is done at the Business Unit level. Therefore, the prime users of the Track Maintenance Advisory System are in Vancouver and Toronto. The Divisions receive paper copies of graphs comparing rail wear, defect statistics and current and past Track Quality Indices. In addition, the Divisions receive advance lists of recommended work program. If the recommended program is not feasible within budgetary limitations, the user may select his own standard and regenerate the program, with the goal of progressively achieving the standard in the future.

TRACK MAINTENANCE ADVISORY SYSTEM - RAIL MODULE															
=====															
SUBDIVISION :		MAIN W LENGTH : 112.725				ALL PROGRAMME YEARS FROM : 0.110 TO : 112.835									
SEGMENT	SEGMENT	DEG	DIR	LEFT	RIGHT	SUPER	LtR	RtR	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	
FROM	TO	OF	OF	RAIL	RAIL	YEARLY	Was	Was	RENEW	RENEW	RENEW	RENEW	TRANS	TRANS	
		CRV	CRV	WEIGHT	WEIGHT	TONNAGE	HIR	HIR	YEAR	YEAR	TQI	TQI	YEAR	YEAR	
=====															
0.394	0.610	2.5	L	100HF	100HF	8.2			****	1991	*****	Rail Wear	****	****	
1.911	2.241	5.0	R	100HF	100HF	8.2			****	1996	*****	Rail Wear	1991	****	
2.912	3.227	4.0	L	100HF	100HF	8.2			****	1996	*****	Rail Wear	****	****	
3.267	3.521	5.0	R	100HF	100HF	8.2			****	****	*****	*****	1994	****	
3.801	3.991	5.1	L	100HF	100HF	8.2			1997	****	Rail Wear	*****	****	****	
4.473	4.612	3.6	R	100HF	100HF	8.2			****	1994	*****	Rail Wear	****	****	
5.028	5.311	4.0	L	100HF	100HF	8.2			****	****	*****	*****	****	1991	
5.311	5.542	4.4	R	100HF	100HF	8.2			1993	1996	Rail Wear	Rail Wear	****	****	
6.705	6.900	3.9	L	100HF	100HF	8.2			****	1993	*****	Rail Wear	****	****	
6.919	7.241	3.9	R	100HF	100HF	8.2			****	****	*****	*****	1995	****	
7.241	7.388	3.8	L	100HF	100HF	8.2			1995	1991	Rail Wear	Rail Wear	****	****	
8.979	9.199	5.1	R	100HF	100HF	8.2			1993	1996	Rail Wear	Rail Wear	****	****	
9.350	9.472	3.0	L	100HF	100HF	8.2			****	****	*****	*****	****	1994	
9.612	9.828	3.9	R	100HF	100HF	8.2			****	1995	*****	Rail Wear	****	****	
9.828	9.949	3.5	L	100HF	100HF	8.2			****	1991	*****	Rail Wear	****	****	
12.830	13.017	3.2	L	100HF	100HF	8.2		Y	****	1995	*****	Rail Wear	****	****	
26.528	26.623	0.0	T	100HF	100HF	8.2			****	1991	*****	RI Defect	****	****	

Figure 8. Sample Report from Rail Module

Sample Report Output from Rail Module

Figure 8 is sample output from the Rail Module of the Track Advisory System. The report defines the curve or tangent location and recommends the year of replacement based upon projection of the rail TQI's from current levels. The TQI that has triggered the recommendation is also highlighted, for example Rail Wear or Rail Defects. If the ratio of lateral to vertical wear exceeds specified limits, and wear is projected to hit limits at which transposal is economical, TMAS may instead recommend that the rail be transposed. The user may also request to see the projected rail TQI's on this report, the ratio of lateral to vertical wear, which may indicate a lubrication problem, and may query whether the rail has field face wear, indicating that it was a former high rail.



Where only the tough survive

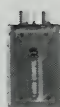
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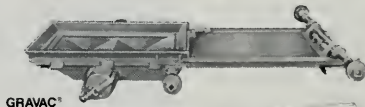
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Direct Input to Rail Grinding

The TMAS system is now integrated with the Graphical Grinding Program Editor, a joint development with Pandrol Jackson and Cole, Sherman. This means that data from the Track Evaluation Car, Corrugation Analyzer, Rail Flaw cars and field observations can be compared with rail longitudinal and transverse profile standards to not only identify locations requiring rail grinding, but to also directly specify the number of passes, grinding speeds and pattern numbers required. The resulting recommendations are output as a Grinding Production Plan, which is given directly to the operator of the production rail grinder. An example is included as Figure 9.

The Grinding Production Plan automatically calculates the time to grind between sidings and the expected daily production as a function of input track occupancies. Personal computers onboard the Pandrol Jackson and Loram grinders dedicated to use on CP Rail System are used by the local CP grinding specialist to edit the grinding plan as the work proceeds.

Benefits of the TMAS Approach

The advantages of the TMAS approach to planning are:

- it promotes allocation of resources to maintain consistent standards appropriate to the class of service;
- it improves the understanding from all levels on the reasons for performing program work;
- it improves our ability to predict future requirements, leading to better resource levelling and long range budgeting;
- it reduces the possibility that a critical location can be missed;
- it paves the way for direct cost justification of track projects;
- it integrates well with detailed production plans for work gangs.

Future Implications for Maintenance of Way

The Track Maintenance Advisory System has helped us to become more predictive in our approach to programmed maintenance. It has displayed the planning assumptions to our people and has increased our confidence in our ability to know our track condition. Together, this allows us to eliminate some excess conservatism and to better tailor our track condition to service demands.

TMAS has reinforced our belief in the value of good track, and in particular in the value of good ballast, which we had found in our studies to significantly affect both rail deterioration and surfacing cycles.

And TMAS has demonstrated that the way to save money is to maintain only that track that must be maintained, and to maintain it at the right time. TMAS is therefore sparking a move away from large out-of-face programs, and more towards addressing specific locations. By concentrating on our worst locations at the expense of out-of-face work, we actually improve track quality as defined by the service levels to traffic.

PUBLISHED AS INFORMATION

COMMITTEE 1 — ROADWAY AND BALLAST

Chairman: W. L. Heide

DIRECTIONAL BORING

Subcommittee Chairman: R. J. Boileau

The railroads are getting more and more pipeline crossing applications that utilize a trenchless installation process called "Directional Boring." Most involve long deep bores which make an encased crossing impractical. Following is a report concerning this relatively new technology.

Directional boring was first used in 1971 and was developed from the directional drilling process used in the oil well drilling industry. It is also referred to as horizontal directional drilling and horizontal guided boring. This technology is used extensively by utility companies for installation of cables and small diameter pipelines in urban areas. It is only used with the larger diameter transmission pipelines for special complicated crossings, such as river crossings. The main advantages of this technology are: avoiding existing utilities, minimizing surface disturbance, and speeding installation. The disadvantages are: too specialized, expensive in small installations, and it requires pipe that can withstand very high axial tensile forces even at joints. It is largely limited to steel pipe in long bore installations.

Larger diameter installations require a two stage operation with the first stage being a small diameter pilot hole being bored on the desired vertical and horizontal alignment. The second stage involves the enlarging of the pilot hole to the desired diameter to accommodate the cable or pipeline. This stage is done in a reverse direction pulling the cable or pipeline into the hole during the enlarging operation. The boring process is by mechanical cutting or by fluid cutting with high pressure jets. The jet process uses a bentonite slurry as a cutting fluid. The mechanical cutting is done by a bit driven by a mud motor and the drilling fluid is the power source. Both methods use some type of surveying system with the bit location being tracked by radio signals. Accuracy is remarkably good but can vary with operator skill.

Following are the primary methods used:

Horizontal Directional Drilling

Pilot hole:	Approx. 3"
Type pipe:	Steel
Size pipe:	3" to over 40"
Bore span:	400 LF to 6000 LF
Depth:	30 ft. +
Accuracy:	Usually 1% of length but depends on survey system and skill of operator.
Ground conditions:	The best is clay and the poorest is gravel and rock.

Guided Boring Method

Also referred to as Flowmole Softbor or Guidedril method.

Pilot hole:	None
Type pipe:	Any type cable or small diameter pipe
Size pipe:	3" to 14"
Bore span:	600 LF
Depth:	13 to 15 ft.
Accuracy:	$\pm 1\%$ drill bit location, directional steering $\pm 3"$ to $\pm 6"$
Ground conditions:	Soft soils, clay and sand best.

Coil Drill Method

Pilot hole:	None
Type pipe:	Any type cable or small diameter pipe.
Size pipe:	3" to 7"
Bore span:	500 LF
Depth:	16 ft.
Accuracy:	$\pm 0.5''$ drill bit location and steering accuracy very high.
Ground conditions:	Clay and sand but has been used in limestone.

Fluid Assisted Mechanical Cutting

Pilot hole:	None
Type pipe:	Any type cable or small diameter pipe.
Size pipe:	3" to 12"
Bore span:	600 LF
Depth:	15 ft.
Accuracy:	$\pm 6''$ drill bit location, steering $\pm 12''$
Ground conditions:	Soft soils, clay and sand.

All of the above methods can be safely installed under railroads but they must be analyzed carefully for each case. The use of casing pipe is a must for shallow installations and for all plastic or jointed pipe. Large diameter pipelines, such as transmission lines, can be installed uncased but should be 10 ft. minimum depth across the entire right of way. Long span bores of 500 ft. or more can not be encased as it would be extremely difficult to maintain separation of the carrier and casing pipe.

This technology is still developing and will no doubt be used more in the future. AREA and the railroad industry must stay aware of future developments so that applications for directional bore crossings can be handled properly.

COMMITTEE 4—RAIL

Chairman: H. W. Newell III

Report of Subcommittee 3 Rail Statistics

Subcommittee Chairman: A. E. Shaw, Jr.

Report of Rail Shipped to North American Railroads* from North American and Non-North American Producing Mills in 1991

By Weight and Section

Weight	Section	Non-N. American Tons (Net)	N. American Tons (Net)	Total	% Total
140	RE	0	1,205	1,205	0.2
136	RE**	88,026	238,044	326,070	59.2
133	RE	38,863	38,931	77,794	14.1
132	RE	30,678	56,016	86,694	15.6
122	CB	0	0	0	0
119	RE	0	368	983	0.1
115	RE	615	50,692	51,307	9.3
100	RE	0	116	116	0
100	RA-A	959	2,399	3,358	0.6
Girder		0	2,160	2,160	0.9
TOTAL		159,141	389,931	549,687	100

*Includes transit agencies.

**Includes 136 # with modified head profile.

NOTE: The report is from data furnished by North American Rail Producers covering rail shipped to railroads, transit agencies and contractors known to supply rails to railroads in North America. The non-North American rail data was obtained by soliciting 54 railroads and major transit agencies as to their purchases of non-North American rail. Of the 54 solicited, 46 responded including all class 1 railroads and all major transit agencies except for three.

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COMMITTEE 28 — CLEARANCES

REPORT OF SUBCOMMITTEE D-6-89
Subcommittee Chairman: G. K. Graham

RECOMMENDED DATA ELEMENTS FOR USE IN RAILWAY DIMENSIONAL SHIPMENT CLEARANCE ELECTRONIC DATA INTERCHANGE (EDI) TRANSACTION SETS

INTRODUCTION: Data Elements for Clearance EDI

Movement of dimensional shipments requires a great deal of coordination between railroads and their shippers, and also between departments within railroads. Much of this communication is accomplished in written form via mail, facsimile, wire services, and direct computer connection. Current shipment clearance analysis techniques are rapidly being computerized and are desperately in need of a suitable EDI standard.

This report contains individual pieces of data which may appear in any of the clearance message types listed below. This data is officially recommended as a guide to any party interested in creating clearance EDI transaction sets. We have attempted to compile data field types and sizes which will accommodate future needs based on current practice and trends.

Clearance Message Types

1. *Proposal*: Request for clearance authority. Sent from shipper to railroad, or between railroads.
2. *Proposal Reply*: Affirmative or negative results of proposal analysis, usually advising loading arrangement which can be handled. Sent between railroads, or from railroad to shipper, with an optional copy to the railroad sales department.
3. *Loading Report*: Description of loading arrangements in detail. Sent from railroad mechanical department inspector to railroad clearance bureau.
4. *Internal Routing*: Route and restrictions governing movement of a shipment within a single railroad. Sent from railroad clearance bureau to railroad operating personnel.
5. *Advance Notice*: Description of loading arrangement and shipping information. Sent as advice at time of movement from original railroad to other railroads involved or concerned.
6. *Obstruction Data*: Description of right-of-way obstruction in detail. Usually sent from railroad clearance measurement field team to the railroad clearance obstruction database.

The data is organized into four main groupings.

- I. *Message Headings*: Determines the type of message being sent as well as to whom, from whom, and date.
- II. *Shipping Information*: Standard shipping information required for determining clearance and which may not otherwise be available to the receiver at time of transmission or analysis.
- III. *Physical Characteristics*: All data required to completely describe a shipment for clearance analysis purposes. Also includes obstruction characteristics.
- IV. *Restrictions*: Those limits or routings which are required or recommended for the safe movement and handling of the shipment, internal or external to a particular railroad. Internal restrictions and routings vary widely from railroad to railroad and must be dealt with on a local basis. This transaction set is therefore limited to only those common restrictions which a railroad may wish to pass on to connecting railroads as information.

Each grouping contains data segments of related or interdependent data elements along with brief explanations of form, content, and conditions of use.

Assume all segments and elements to be optional unless otherwise noted.

Much of the information found in the "message headings" and "shipping information" sections are common to other business forms and an existing standard format is assumed to be available. On the other hand, the information contained in the "physical characteristics" and "restrictions" groupings may break a considerable amount of new ground.

Please see the Appendix for examples of "typical" clearance messages.

DATA ELEMENTS:

I. Message Headers

1. To: name, title, company, address (electronic and/or street), recipient's reference file number (if known) and file date.

Use standard formats for all but reference file, which should be a free-form, 20 character field.

This segment is required once per message, but optionally repeatable to permit transmission of a message to a large number of recipients (1 to 1000).

A storage device code could be used as a substitute for "name" to allow a message to be composed and sent to an electronic file without specifying a name or company.

2. From: name, title, company, address (electronic and/or street), sender's file number and file date.

Use standard formats for all but reference file, which should be a free-form, 20 character field.

This segment is required once per message. Either "name" or "company" is required. All other elements are optional.

3. Date & time of transmission.

Use standard format.

4. Report type, modifier, modifier, modifier, modifier ...

Use a single digit field for "type" as follows: n

One of the following required per message:

- 1 = Proposal. (Can you handle the following?)
- 2 = Proposal Reply. (Regarding your proposed shipment ...)
- 3 = Loading Report.
- 4 = Internal Routing.
- 5 = Advance Notice. (Please project.)
- 6 = Obstruction Data.

Types 4 and 5 may be optionally combined at time of message composition, but separate reports are recommended.

Use a two digit field for "modifier" as follows: nn

- 1 = Please advise maximum if unacceptable
- 2 = Please advise alternate routing if unacceptable
- 3 = Please advise nearest point to which shipment can be handled
- 4 = We can handle as proposed
- 5 = We regret we cannot handle as proposed
- 6 = We can handle the following loading arrangement via route(s) and/or to locations shown
- 7 = In special train service (see restrictions section)

- 8 = In regular train service
- 9 = Advance notice is required
- 10 = Please rush reply—extremely urgent
- 11 = Please expedite this time-sensitive shipment.

II. Shipping Information

5a. Origin rail station, SPLC number, siding name and/or number.

Use standard formats for station name and SPLC number. Use free-form, 80 character field for siding name and free-form, 20 character field for siding number.

5b. Shipper information: Contact name, title, company, address, reference file number and date.

Use same formats as segment 1 under "message headers" section.

6a. Destination rail station, SPLC number, siding name and/or number.

Use standard formats for station name and SPLC number. Use free-form, 80 character field for siding name, free-form, 20 character field for siding number.

6b. Consignee information: Contact name, title, company, address, reference file number and date.

Use same formats as segment 1 under "message headers" section.

7. Waybill route (railroad, interchange, railroad, interchange, ..., railroad).

Clearance applications require each item to be accessible separately. Therefore, each railroad and interchange point must have its own field.

If a standard is not available, use a four character alpha field for railroad, and station name field as used in segment 5 (origin station) or 6 (destination station) for the interchange point, alternating between the two as needed. If an interchange point is not known, it may be left blank.

8. Commodity, STCC, description, value.

Use free-form field for "commodity" and "description" as this is not a strict tariff-recognized usage. Use standard format available for Standard Transportation Commodity Code (STCC). Use standard format for value if capable of up to twelve digits as follows: n,nnn,nnn,nnn.nn

9. Waybill number and date.

Use standard format.

10. Estimated loading date, release date, arrival time at "station X."

Use standard formats. "Station X" should use same format as segment 5 "original rail station."

11. Now on hand at "station Y."

Same format as "station X" in segment 10.

Required by "loading report" and "internal routing." Optional in others.

III. Physical Characteristics

12. Load type.

Use a single numeric character 1, thru 9, as shown:

- 1 = single load (one load car, no idlers)
- 2 = double load (bolster load on two cars, no center idlers)
- 3 = triple load (bolster load on two cars with single center idler)
- 4 = quad. load (bolster load on two cars with two center idlers)

- 5 = bolster load with three center idlers
- 6 = bolster load with four center idlers
- 7 = bolster load with five center idlers
- 8 = bolster load with six center idlers.

Required in all report types except "Obstruction data."

13. Overhang type.

Use a single numeric character, 0 thru 2, as shown:

- 0 = no overhangs
- 1 = single end overhang
- 2 = double end overhang

Required in all report types except "Obstruction data."

14. Obstruction description, type code, milepost, line name, line code, division code, subdivision code, track number, degree of curvature, superelevation, bridge deck type.

Use 30 character free-form field for description.

Use 2 character alpha field for obstruction type code, as shown:

- OH = overhead bridge
- OW = overhead wire
- TN = tunnel
- PG = plate girder bridge
- TT = through truss bridge
- AB = abutment or retaining wall
- RC = rock cut
- LP = telephone or communications line poles
- CT = electrical catenary poles
- TW = trolley wire
- SG = wayside signal mast or head
- DW = dwarf signal
- BR = brush, trees, or other plants
- XX = not shown

Use 11 character field for milepost as follows: aannnn.nnnaa

Use 10 character free-form field for line code, division code, and subdivision code.

Use nine character free-form field for track number.

Use four digit field for degree of track curvature (decimal degrees) as follows: nn.nn. Note that a *positive* value indicates a curve to the right, and a *negative* value indicates a curve to the left when looking in the direction provided in item 22.

Use three digit field for superelevation (decimal inches) as follows: n.nn. Note that a *positive* value indicates the lower rail is on the right, and a *negative* value indicates the lower rail is on the left when looking in the direction provided in item 22.

Use single digit field for deck type as follows: n

- 1 = open deck
- 2 = ballast deck

15. Equipment Characteristics. This segment or section must be repeated for each car involved in the shipment, although not every element must be completed for each car. The UMLER-type information is included here to cover equipment which may not be listed in UMLER or the Equipment Register. (UMLER is the Universal Machine Language Equipment Register)

15a. Car Initial.

Use UMLER standard.

15b. Car number.

Use UMLER standard.

15c. Car use in this shipment.

Use two numeric character field for code as shown:

- 1 = Load car 1 (repeat for identical single loads)
- 2 = Load car 2
- 3 = End idler 1
- 4 = End idler 2
- 5 = Center idler 1
- 6 = Center idler 2
- 7 = Center idler 3
- 8 = Center idler 4
- 9 = Center idler 5
- 10 = Center idler 6
- 11 = Locomotive dead in tow, moving on own wheels
- 12 = Locomotive crane, moving on own wheels
- 13 = Hot metal car, moving on own wheels
- 14 = M/W equipment, moving on own wheels
- 15 = Passenger coach, moving on own wheels
- 16 = Coke quench car, moving on own wheels
- 20 = Free form, use as needed

15d. Length over end sills "C."

Use standard UMLER-type format if available.

15e. Coupled length "CL."

Use UMLER format for outside length.

15f. Truck centers "D" (or body center-plate spacing for span-bolster cars).

Use UMLER format for truck center spacing without maximum limitation.

15g. Distance from bolster to nearest truck center "T."

Use one three digit and one four digit numerical field for feet and inches: nnn nn.nn

15h. Midordinate swingin (swingout).

Swingin/swingout of car body in inches per degree of track curvature, usually as reported by carbuilder. A *positive* value indicates swing toward the inside of the curve. A *negative* value indicates swing toward the outside of the curve.

Use UMLER format.

15i. Base length of load.

Length of load or bolster actually bearing on the car in feet and inches: nnn nn.nn

15j. Net weight.

Weight of load and dunnage, tie down material, etc., or that portion of load & etc. bearing on the car. Lbs.

Use seven digit numerical field: n.nnn,nnn

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15k. Light weight.

Weight of railcar only.

Use UMLER format.

15L. Gross weight.

Total weight on rail in Lbs. Light weight plus net weight. (15j + 15k = 15L).

Use seven digit numerical field: n.nnn.nnn

15m. Load limit.

Use UMLER format.

15n. Number of axles.

Give option to use UMLER format or a three digit numerical field: nnn

15o. Number of trucks.

Use three digit numerical field: nnn

15p. Gear ratio.

Used only for locomotives.

Use UMLER format, if available, or a four digit numerical field: nn:nn

15q. Pinions connected?

Used only for cranes. Yes or no answer. Use single character field.

If numerical value required,

1 = yes, 2 = no.

If alpha character required,

y = yes, n = no.

15r. Hand brakes operable?

Yes or no answer. Same format as 15q.

15s. Air brakes operable?

Reply may be: yes, no, or piped for straight air (brake system bypassed). Use single character field.

If numerical value required,

1 = yes, 2 = no, 3 = piped.

If alpha character required,

y = yes, n = no, p = piped.

15t. Air brake type.

Use UMLER format.

15u. Draft gear and coupler type.

Use UMLER format.

15v. Manufactured by?

Use 80 character free-form field.

15w. Date built.

Use UMLER format with option to fill in only year, or month and year, if that is all that is known.

15x. Axle 1 load, wheel diameter, journal size, journal type.

Use fields as follows:

Axle load (lbs): nnn.nnn.nn

Wheel dia (in): UMLER format

Journal size (in X in): UMLER format

Journal type (friction or roller bearing): UMLER

15y. Axle "N" load, wheel diameter, journal size, journal type, distance from axle "N-1."

Repeat from "N" = 2 to number of axles (15n).

Use same fields as 15x with addition of:

Distance from axle "N-1" (ft.in): nn, nn.nn

15z. Vertical center of gravity of car.

Use UMLER format.

16. Combined vertical center of gravity, modifier.

Use five digit numerical field for inches ATR: nnn.nn

Use single digit field for modifier as follows:

1 = assumed value.

2 = calculated by railroad.

3 = provided by shipper.

17. Transverse center of gravity.

Use four digit numerical field for inches from centerline of car: nn.nn

18. Longitudinal center of gravity.

Use one three digit and one four digit numerical field for feet and inches from nearest truck center, bolster center or pivot point: nnn nn.nn

19. AAR loading rules section and figure.

Use six character field: cccccc

20. Overall length of load "L."

Use two four digit fields, one for feet and one for inches: nnnn nn.nn

21. Bearing spacing or bolster spacing (for multiple load) "B."

Use one three digit and one four digit numerical field for feet and inches: nnn nn.nn

22. Cross section type, half width "X," height ATR "Y," position "Z," direction of view, comment.

Use single character for "type" as follows:

1 = Cross section of load between truck centers

2 = Section outside truck centers, overhang 1

3 = Section outside truck centers, overhang 2

4 = Right of way obstruction

Use numerical formats for "X," "Y," and "Z," in feet and inches as follows:

X = nn nn.nn (X=0.00 at centerline of track. Right of centerline is positive, left is negative, as defined by "direction of view")

Y = nn nn.nn (Y = 0.00 at top of rail)

- Z = nnn nn.nn (Z=0.00 at truck center or pivot point. Overhang length is positive.
Position between truck centers is positive, measured from truck center
to truck center or bolster to bolster in direction of view.
Z = 0.00 at entry of obstruction such as a tunnel.)

Use single character field for "direction of view": n

- 1 = looking west (timetable direction)
- 2 = looking east (timetable direction)
- 3 = looking north (timetable direction)
- 4 = looking south (timetable direction)
- 5 = looking from "B" end toward "A" end of car
- 6 = looking from "A" end toward "B" end of car
- 7 = looking from load car 1 toward load car 2
- 8 = looking from load car 2 toward load car 1
- 9 = looking from low milepost toward high milepost
- 0 = looking from high milepost toward low milepost

Note: 1 thru 4, 9 & 0 apply to obstructions. 5 thru 8 apply to loaded shipments.

Use single character field for "comment": n

- 1 = symmetrical about track centerline
- 2 = diameter
- 3 = car floor
- 4 = tangent line
- 5 = trolley wire
- 6 = 20 character free form

IV. Restrictions

23. Speed limit type, limit, weight of rail.

Use single digit field for "type" as shown: n

- 1 = shipper's requested limit
- 2 = mechanical department recommended limit
- 3 = high value limit
- 4 = hazmat limit
- 5 = limit while on sidings or yard tracks
- 6 = limit while on super-elevated track
- 7 = limit while on "nnn" or lighter rail
- 8 = 80 character free-form

Use five digit field for limit (mph) as shown: nnn.nn

Use three digit field for weight of rail (lbs/yd) as shown: nnn

24. Precede and follow instructions.

Use a single digit field as follows: n

- 1 = precede and follow with one or more empty cars, account weight.
- 2 = precede and follow with one or more empty cars with minimum coupled length of 50 feet, account weight.
- 3 = precede and follow with one or more standard cars with maximum gross weight of 263,000 lbs.
- 4 = precede and follow with one or more standard flats or low-side gondolas to permit observation.
- 5 = free form.

25. Placement in train, maximum gross tonnage in train, number of cars in train, distance from front/rear.

Use single digit field for placement in train as follows: n

- 1 = Free form.
- 2 = place on head end of train within "X" cars of locomotive consist.
- 3 = place on rear end of train.
- 4 = place within "X" cars of rear end of train.
- 5 = must travel with boom end trailing.
- 6 = must travel with "A" end trailing.
- 7 = must travel with "B" end trailing.
- 8 = must travel with load car 1 trailing.
- 9 = must travel with load car 2 trailing.
- 0 = do not subject to pusher service.

Use five digit field for "max gross tonnage in train" (tons) as follows: nnnnn

Use three digit field for "max number of cars in train" as follows: nnn

Use three digit field for number of cars "X" used in instructions 2 or 4 above as follows: nnn

26. Rider information: name, title, company, address (electronic and/or street), riding from "station A" to "station B."

Use same formats for name, title, company, and address as used for segment 1.

Use same formats for "station A" and "station B" as used for segment 5.

27. Special freight train requirement: from "station A" to "station B," number of miles from A to B, current rate per mile, current minimum charge.

Completion of any element indicates special train requirement.

Used same formats for "station A" and "station B" as used for segment 5.

Use six digit field for "miles" as follows: nnnn.nn

Use five digit field for "rate" as follows: nnn.nn

Use seven digit field for "minimum charge" as follows: nn, nnn.nn

28. Circuitous internal route: normal miles, circuitous miles, percent over normal miles.

Completion of either normal and circuitous miles or percent will indicate circuitous internal route.

Use six digit field for normal miles and for circuitous miles as follows: nnnn.nn

Use four digit field for percent as follows: nnn.n

29. Internal route and restrictions.

Use unlimited free-form.

30. Free-form note.

Use unlimited free-form to cover any omission in this transaction set. To be used only as a last resort.

31. Measured by: name, title, company, address and phone.

Use standard formats.

32. Clearance authority prepared by: name, title, company, address and phone.

Use standard formats.

APPENDIX: Notes from A.R.E.A. Committee 28

Committee 28 members were asked to comment on this document as part of the approval process. Most of the comments were of an editorial nature, and the changes have been included in the preceding text. One major change involved the inclusion of obstruction type codes shown in item 14. The codes have not been approved by the committee, but for the purposes of creating a transaction set, the only important information is the need for a two-character field. Committee 28 can decide what the codes should be at a later date.

One Committee 28 member commented that much of the information in this report is good for internal communication, but does not have to be conveyed between carriers. In his opinion, too large an EDI report would only promote errors. He would like to keep the EDI transmission as simple as possible and each carrier can expand on that transmission internally to handle clearance matters in an expeditious fashion.

One other member recommended that we include copies of the loading diagrams prepared by the AAR on which we have based the physical characteristics nomenclature. Please refer instead to the Association of American Railroads "General Rules Governing the Loading of Commodities on Open Top Cars, Section No. 1, Part 2: Recommended Procedures for Measuring Loads Which Exceed Published Railway Line Clearances." Another source of these diagrams is the AAR section in "Railway Line Clearances," published by K-111 Information Company, Inc., 424 West 33rd St., New York, NY 10001. Telephone (212) 714-3100.

It is possible that railroads may want to link an EDI clearance message to an EDI waybill, or to EDI billing information in order to provide a complete picture to those parties responsible for collecting revenue and assigning rate authority. This capability should be considered by future transaction set designers.

Other committee 28 members suggested that sample messages be included to demonstrate the way information is currently being passed.

Sample Messages

Please examine the sample messages which follow. These hypothetical messages do not necessarily represent recommended practice nor any particular carrier's policy toward movement of dimensional shipments. They are offered to aid the reader's understanding of how clearance departments communicate basic data. They are of average complexity. Many messages are less detailed, but some are much more complex. Be advised that no two railroads structure their messages the same way. There are MANY variations on the following formats.

Messages:

- Proposal
- Proposal Reply
- Advance Notice
- Loading Report
- Internal Routing Report
- Obstruction Data Report

Typical Clearance Messages—A Proposal

TO: CR CLEARANCE BUREAU—PHILA, PA
FROM: BN CLEARANCE BUREAU—OVERLAND PK, KS
DATE: 1/24/91
WE HAVE BEEN OFFERED SHIPMENTS OF CYLINDRICAL VESSELS
DESTINED LOCKPORT NY ROUTED BN—STREATOR—CR.
THE SHIPMENTS WOULD HAVE AN OVERALL LENGTH OF 50 FT 0 IN, A
NET WEIGHT OF 100000 LBS AND WOULD BE LOADED ON 60 FT OR

SHORTER FLATS WITH MAX 50 FT 0 IN TRUCK CENTERS PRODUCING A SHIPMENT MEASURING WITHIN:

0 FT 0 IN WIDE AT 17 FT 0 IN ATR ROUNDING TO

13 FT 0 IN WIDE AT 10 FT 6 IN ATR

13 FT 0 IN WIDE AT 10 FT 0 IN ATR ROUNDING TO

10 FT 6 IN WIDE AT 3 FT 6 IN IN ATR

ADVISE QUICK IF CAN HANDLE OR MAXS.

HW 19366-11

BN CLEARANCE BUREAU

Data elements required for the above message:

Message headers, items 1, 2, 3, & 4 (multiple modifiers).

Shipping information, items 6a, 7, & 8.

Physical Characteristics, items 12, 13, 15c, 15d, 15f, 15j, 20, 22 (substituting comment 2 "diameter" for use of phrase "rounding to" for more accuracy).

Typical Clearance Messages—A Proposal Reply

TO: BN CLEARANCE BUREAU—OVERLAND PK, KS

BN FILE HW 19366-11

FROM: CR CLEARANCE BUREAU—PHILADELPHIA, PA

CR FILE 10079

DATE: 1/25/91

REGARDING YOUR PROPOSED SHIPMENTS OF CYLINDRICAL VESSELS DESTINED LOCKPORT, NY ROUTED BN—STREATOR—CR.

WE CAN HANDLE AS PROPOSED. ADVANCED NOTICE IS REQUIRED.

OVERALL LENGTH OF 50 FT 0 IN, NET WEIGHT OF 100000 LBS

LOADED ON 60 FT FLATS WITH MAX 50 FT 0 IN TRUCK CENTERS MEASURING WITHIN:

17 FT 0 IN ATR 00 FT 0 IN WIDE

10 FT 6 IN ATR 13 FT 0 IN WIDE DIAMETER

10 FT 0 IN ATR 13 FT 0 IN WIDE

3 FT 6 IN ATR 10 FT 6 IN WIDE

CLEARANCES AUTHORITY PREPARED BY JOHN DOE, ENGINEER—

CLEARANCES, CR CLEARANCE BUREAU, PHONE 123-456-7890

Data elements required for the above message:

Message headers, items 1, 2, 3, & 4 (multiple modifiers).

Shipping information, items 6a, 7, & 8.

Physical Characteristics, items 12, 13, 15c, 15d, 15f, 15j, 20, 22

Restrictions, item 32.

Typical Clearance Messages—Advance Notice.

TO: CR CLEARANCE BUREAU—PHILA, PA

FROM: BN CLEARANCE BUREAU—OVERLAND PK, KS

DATE: 4/22/91

NOW RELEASING LOADED SHIPMENTS OF CYLINDRICAL VESSELS DESTINED LOCKPORT, NY ROUTED BN—STREATOR—CR.

PLEASE PROTECT, YOUR FILE 10079 DATED 1/25/91.

THE SHIPMENTS ARE LOADED ON CARS BN 123456 and CR654321, AND HAVE AN OVERALL LENGTH OF 50 FT 0 IN, A NET WEIGHT OF 100520 LBS, WITH 50 FT 0 IN TRUCK CENTERS.

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ALL LOADED CARS MEASURING WITHIN:
0 FT 0 IN WIDE AT 17 FT 0 IN ATR
13 FT 0 IN WIDE AT 10 FT 6 IN ATR DIAMETER
13 FT 0 IN WIDE AT 10 FT 0 IN ATR
10 FT 6 IN WIDE AT 3 FT 6 IN ATR
HW 19366-11
BN CLEARANCE BUREAU

Data elements required for the above message:

Message headers, items 1, 2, 3, & 4 (multiple modifiers).

Shipping information, items 6a, 7, & 8.

Physical Characteristics, items 12, 13, 15a, 15b, 15c (load car 1 used twice), 15d, 15f, 15j, 20, 22.

Typical Clearance Messages—Loading Report.

TO: CR CLEARANCE BUREAU—PHILA, PA
FROM: CR MECHANICAL DEPARTMENT—STREATOR, IL
DATE: 5/12/91 1345 HOURS
NOW ON HAND AT STREATOR, IL. COMMODITY: STEEL TANKS
DESTINED LOCKPORT, NY ROUTED BN—STREATOR—CR.
LOADED ON BN 123456 AND CR 654321.
SINGLE LOADS, NO END OVERHANGS.
LENGTH OVER END SILLS 60 FT 8 IN.
TRUCK CENTERS 50 FT 0 IN.
BASE LENGTH OF LOAD 45 FT 0 IN. OVERALL LENGTH OF LOAD 50 FT
0 IN. NET WEIGHT 100520 LBS, LIGHT WEIGHT 67500 LBS, GROSS WEIGHT 168020 LBS.
LOADED CARS MEASURING WITHIN:
17 FT 0 IN ATR 0 FT 0 IN WIDE
15 FT 0 IN ATR 10 FT 2 IN WIDE
10 FT 6 IN ATR 12 FT 11 IN WIDE
10 FT 0 IN ATR 12 FT 11 IN WIDE
3 FT 6 IN ATR 10 FT 6 IN WIDE
MEASURED BY JOHN DOE, CAR INSPECTOR, STREATOR, IL.

Data elements required for the above message:

Message headers, items 1, 2, 3, & 4.

Shipping information, items 6a, 7, 8, & 11.

Physical Characteristics, items 12, 13, 15a, 15b, 15c (load car 1 used twice), 15d, 15f, 15i, 15j, 15k, 15L, 20, 22.

Restrictions, item 31.

Typical Clearance Messages—Internal Routing Report.

TO: GENERAL MANAGER—CHICAGO DIVISION
WAYBILLING DEPARTMENT—CUSTOMER OPERATIONS CENTER
MECHANICAL DEPARTMENT—STREATOR, IL
TRAINMASTER—STREATOR, IL
TRAINMASTER—TOLEDO, OH
TRAINMASTER—BUFFALO, NY

FROM: CR CLEARANCE BUREAU—PHILADELPHIA
FILE: 10079 DATE: 5/12/91 1634 HOURS

NOW ON HAND AT STREATOR, IL. COMMODITY: STEEL TANKS
DESTINED LOCKPORT, NY ROUTED BN—STREATOR—CR.
LOADED ON BN 123456 AND CR 654321.
SINGLE LOADS, NO END OVERHANGS.
OVERALL LENGTH OF LOAD 50 FT 0 IN. NET WEIGHT 100520 LBS.

LOADED CARS MEASURING WITHIN:

17 FT 0 IN ATR 0 FT 0 IN WIDE
15 FT 0 IN ATR 10 FT 2 IN WIDE
10 FT 6 IN ATR 12 FT 11 IN WIDE
10 FT 0 IN ATR 12 FT 11 IN WIDE
3 FT 6 IN ATR 10 FT 6 IN WIDE

ACCOUNT HIGH VALUE, MAXIMUM SPEED 35 MPH.
PLACE ON HEAD END OF TRAIN WITHIN 20 CARS OF LOCOMOTIVE CONSIST.
SHIPMENT IS ACCOMPANIED BY RIDER, JIM DOE, DOE'S EXPEDITING.

HANDLE CAREFULLY IN YARDS, AROUND SHARP CURVES AND WHERE
TRACK CENTERS ARE CLOSE.
NOTIFY TRAIN DISPATCHERS, YARDMASTERS, TRAIN CREWS AND
OTHERS INTERESTED. CONNECTING DIVISIONS TO BE GIVEN ADVANCE
INFO AS TO PROBABLE DELIVERY.

ADJACENT MAIN AND SECONDARY TRACKS MUST BE CLEAR OF ALL OTHER
EQUIPMENT. DIVISIONS INVOLVED TO ARRANGE FOR
CLEARANCE WHILE PASSING EQUIPMENT ON ADJACENT SIDINGS AND
THRU YARDS.

STREATOR—ELKHART—TOLEDO—AVOID TOLEDO STATIONMASTERS
SHED MP 214.20 ON MAINLINE—BUFFALO—MUST RUN VIA CP 2 TO
CP 437 AVOIDING THRU TRUSS BRIDGE 435.30 BUFFALO CREEK—
CP 81—LOCKPORT.

JANE DOE, CONRAIL CLEARANCE BUREAU, 5-555-5555.

Data elements required for the above message:

Message headers, items 1 (repeated many times), 2, 3, & 4.

Shipping information, items 6a, 7, 8, & 11.

Physical Characteristics, items 12, 13, 15a, 15b, 15c (load car 1 used twice), 15j, 20, 22.

Restrictions, items 23, 25, 26, 29, 32.

Typical Clearance Messages: Obstruction Data Report.

To: Clearance Bureau
From: Clearance Field Team, MW vehicle ID x-12345/HW
Date: 4/1/90
RE: Obstruction Data Report

Obstruction Description: Monongahela River
Obstruction Type: TT Through Truss Bridge
Milepost: 437.65
Line Name: Pittsburgh Line
Line Code: 2200
Division Code: 22
Subdivision Code: none

Track Number: 001
Degree of Curvature: 03.25
Superelevation: 1.50
Bridge Deck Type: Open
Cross Section: Looking West

Height Above		Width Left		Width Right	
Top of Rail		of Center		of Center	
FT	IN	FT	IN	FT	IN
19	06	05	10.00	06	00
19	03	05	10.00	06	00
19	00	05	10.50	06	00
18	09	05	10.75	06	00
18	06	06	00.00	06	00
17	06	06	00	06	00
17	06	07	00	06	06
03	00	07	00	06	06
02	09	06	06	06	03
02	06	06	00	05	10
02	03	05	08	05	06
02	00	05	06	05	06
01	00	05	00	05	00
00	00	05	00	05	00

Measured by Jim Doe, Assistant Clearance Engineer, 5-555-5555.

Data elements required for above message:

- Message headers, items 1, 2, 3, & 4.
- Shipping information, none.
- Physical characteristics, items 14 & 22.
- Restrictions, item 31.

MEMOIR

Thomas L. Fuller

Thomas L. Fuller died in Austin, Texas on February 8, 1992.

Mr. Fuller was a native of Austin, though most of his engineering career was spent in California while working for the Southern Pacific Railroad. During World War II, he served as an officer in the Navy. Tom is survived by his wife Nanette, three children, and four grandchildren.

Mr. Fuller had a long and very distinguished career with the railroad industry, having been employed by the Southern Pacific for 33 years, before his retirement in 1981 as Engineer of Bridges. Upon retirement Mr. Fuller went to work as Regional Manager for Harland Bartholomew & Associates and retired for a second time from this position in 1985.

Mr. Fuller was a continuous active member of AREA Committee 8 from 1963 until his death, having served as Subcommittee Chairman, Vice Chairman, and then Chairman of Committee 8 from 1973 to 1976. Mr. Fuller served as an AREA Director from 1976 to 1978. He joined the Bridge & Building Association in 1959, was elected Director in 1965 and subsequently elected President of the Association.

Mr. Fuller's long and devoted service to the railroad industry and particularly to the American Railway Engineering Association will be greatly missed. Committee 8 notes the loss of Mr. Fuller who was particularly recognized by the status of Member Emeritus.

Prepared by AREA Committee 8

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Stefanie Streever, Editor

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**DEDICATION
TO
JORGE TAMAYO LOPEZ PORTILLO**



**This A.R.E.A. Bulletin is Dedicated to
JORGE TAMAYO LOPEZ PORTILLO**
Director General Ferrocarriles Nacionales de Mexico
(here shown talking to a television reporter in Chihuahua).
In acknowledgement of Mr. Tamayo's excellent leadership
of the Mexican Railways and his support of the A.R.E.A.
and its 1992 meeting in Chihuahua, Chihuahua, Mexico, November 11-13.



A.R.E.A. FALL CONFERENCE IN CHIHUAHUA, MEXICO

Jorge Tamayo, Director General of the National Railways of Mexico, opens the A.R.E.A. Fall Technical Conference in Chihuahua with forceful and appropriate remarks that kept the attention of the audience, a portion of which is shown below.





Above, Sr. Eduardo Barousse, Assistant General Director for Infrastructure and Telecommunications, is introduced. At his side is Sr. Carlos Davalos, A.R.E.A. Board Member.

At left below, Mr. Edwin Harper, President of the Association of American Railroads gives his talk, followed by A.R.E.A. President Bill Glavin, at right.

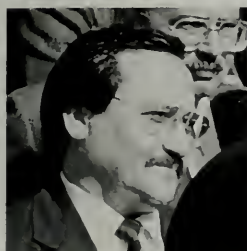




Mr. Tamayo receives the Special A.R.E.A. Award for Improvement in International Transportation in North America that was awarded to Andres Caso, Chairman of the Board of the National Railways of Mexico and Secretary of Communications and Transport in the Mexican Government.

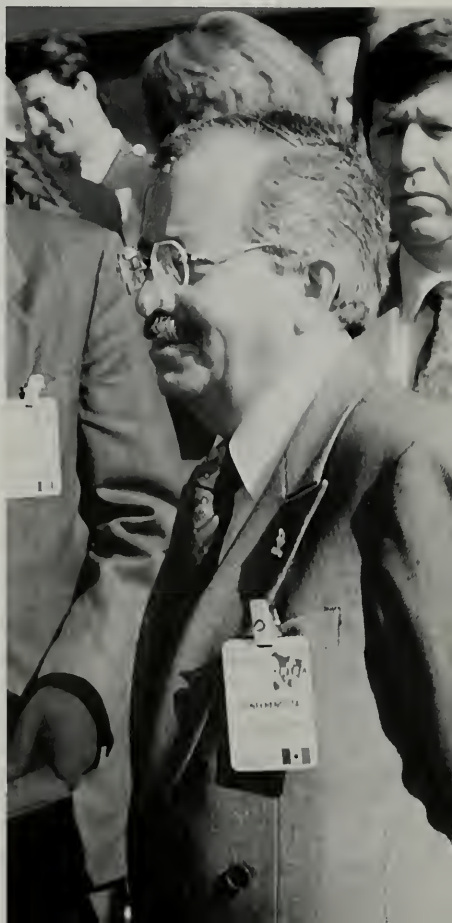
Below, exhibits provided by the National Railways of Mexico were the subject of much interest.





Jorge Tamayo addresses the group (above) as the rest of the head table listens, and (below) talks with other conferees outside the meeting auditorium in Chihuahua. At left, is Gustavo Baca, Manager of the Northern Region of the National Railways of Mexico.

Three representatives from Central America are (left to right) Americo Hidalgo, CEPA Manager in El Salvador, Guillermo Gutierrez of Honduras, President of the Council of Central American Railways (COCAFER), and Gerardo Zepeda of Guatemala, SIECA Assistant Secretary.





Conferees, including Mr. Tamayo and Mr. Barousse, leave auditorium in Chihuahua where technical sessions were held.

DISCURSO DE DIRECTOR EJECUTIVO CERNY 12 DE NOVIEMBRE, 1992, CHIHUAHUA, MEXICO

Nosotros, los ferrocarrileros de Canadá, México y los Estados Unidos nos damos mutuamente la bienvenida al iniciar esta reunión. Tenemos una red ferroviaria en tres países. Las vías interconectadas de los tres países de este continente tienen el mismo ancho entre los rieles. Desde el Río Suchiate en la frontera de Guatemala hasta los territorios del Noroeste de Canadá, somos una red.

En el pasado, muchas personas pensaban en un mapa del transporte en los Estados Unidos y Canadá con una orientación horizontal. El gran concepto era de los ferrocarriles del este al oeste. Pero ahora, tenemos una visión de eje principal de ferrocarriles con una orientación vertical, del sur al norte y vice versa, un eje para incluir todos los tres países de este continente. Cuando vemos que el puerto en el Pacífico mas cerca de Toronto, Canadá es Topolobampo en México, podremos entender la verdad de la orientación vertical del norte al sur.

Como escucharemos en la primera presentación técnica, esta red ferroviaria incluirá tal vez en el futuro los países de Centro América también.

Es muy importante que los ingenieros Mexicanos formen parte de la corriente principal del desarrollo de la ingeniería ferroviaria en este continente, y la A.R.E.A. se esforzará para asegurar que la diferencia de idiomas no impidan este objetivo. Deseo expresar mi profundo reconocimiento al Director General Lic. Jorge Tamayo por su aliento y apoyo a esta reunión, y a todas esas otras personas en los Ferrocarriles Nacionales de México que tanto han contribuido a hacer de esta reunión un éxito, especialmente con el viaje de mañana a Mazatlán.

Quiero decir que el personal de la sede de la A.R.E.A., estamos para servir a los miembros de la A.R.E.A. y para servir a los ferrocarriles de este continente. Sientase con libertad de recurrir a nosotros si podemos ayudarles.

Finalmente, la A.R.E.A. quiere hacer una presentación especial al Sr. Andres Caso Lombardo. Todas las personas aquí presentes sabemos que el licenciado Sr. Caso es uno de los líderes mas importantes en el campo de transporte en este continente. Es ciertamente apropiado que el reciba este reconocimiento de todo este continente por sus logros. Durante su servicio como Director General de los Ferrocarriles Nacionales de Mexico, el mejoró mucho la operacion de los trenes para asegurar un transporte confiable entre los tres países. Y por supuesto, en su posicion actual como secretario de comunicaciones y transportes continua alcanzando mejoramientos importantes en transportación. En vista que el Sr. Licenciado Caso no pudo estar con nosotros el dia de hoy, Voy a suplicar al Sr. Licenciado Tamayo que tengo la bondad de ser el amable conducto para hacerle llegar esto nuestro de reconocimiento la cual dice: "Esta nuestro de reconocimiento de la A.R.E.A. es presentada a Andrés Caso Lombardo para honrar sus logros de mejoramiento del transporte internacional del continente de Norte America."

CONSTRUCTION OF THE VIADUCT-TUNNEL “EL PENSIL” FOR THE POTRERO-PASO DEL MACHO RELOCATION ON THE MEXICO CITY-PUERTO VERACRUZ ROUTE

By: Ing. Fernando A. Rivera Galvan* and Ing. Victor R. Terrazas Cazares*

Background

The National Railways of Mexico, through the general subdirection of infrastructure and telecommunications, has led a modernization program for the national railroad infrastructure. The Mexico City-Veracruz Line, the oldest in the country, is included in this program. Called the “Mexican Railroad,” it is one of the most important railroad routes of the Mexican Republic. To achieve modernization on the line’s critical stretches the grade was reduced from 4.1% to a 2.5% maximum, and the curvature from $11^{\circ} 36'$ to a 6° maximum.

Another critical stretch is between the Potrero and Paso Del Macho villages in the state of Veracruz, where the “El Pensil” viaduct-tunnel structure is located. It was necessary to build “El Pensil” in order to link the gap between the “Atoyac” tunnel, 150 meters in length, and the “Atoyac-Chiquihuite” viaduct, 496 meters long.



Viaduct tunnel “El Pensil.”

The viaduct-tunnel “El Pensil” has special structural characteristics due to the scarce support available on the hillside of the mountain. This led to the use of any unusual technique consisting of a superstructure made of six modules, each with a 15 meter clearance, and utilizing trapezoidal shaped concrete girders. The superstructure is supported on special post-tensioned concrete elements in cantilever called “knives.” They were anchored to the soil by means of prestressed bars, and the hillside was compressed by a rigid reinforced concrete element. It was also necessary to protect the track against hillside landslides by building a reinforced concrete vault.

*National Railways of Mexico

Previous Studies

Surveying

A detailed survey of the zone was made. It included the exit portal of the Atoyac Tunnel to the abutment of the Atoyac-Chiquihuite Viaduct. The information obtained was:

- A detailed plan with curve levels every 0.50 meters.
- Cross sections for every 5.00 meters.

Geological Studies

The structure is located on the right bank of the Atoyac River on a high cliff 80 meters in height and 50 meters above the bottom of the river. This cliff is located in a canyon formed by the erosion of the river. The zone studied is located in the Atoyac Mountain Range near the east boundary of the Madre Mountain Range where there is a series of land folds in a northwest to southeast direction. The Atoyac Range is formed of limestone.

At the viaduct site, there are two lithological units. The first one is formed by limestones that belong to the Atoyac formation in the upper cretaceous. They are covered by a talus deposit and recent organic soil materials as a second unit. The rock exposure in the river is limestone interstratified with clay.

Foundation Studies

In order to know the rock quality for the foundation work, two boring tests, 40 meters in length each, were carried out. The diamond drill rotation procedure NQ (4") was used and rock cores were obtained. They were used to create the stratigraphic profiles for the zone under study. Also, the rock quality designation (R.Q.D.) was determined for the rock mass.

Samples of the rock cores showed that the rock quality varies from regular to very poor, being classified as a severely fractured and weathered dolomitic limestone with clay filling. Taking into account the degree of fracturing it was decided to proceed with the foundation work by means of a system of elements anchored to the cliff. This approach would also improve the condition mentioned above.

Anchor Tests

Because of the type of stratification of the area, anchor tests were done to determine the behavior of the rock mass. This way the capacity and characteristics of the anchors could be obtained.

The study included 10, 15, 19 and 22 meter lengths for 4, 6 and 8 meter embedments. The behavior of the strata in relation to direction was checked as follows:

- Anchors parallel and horizontal to the apparent direction of the strata.
- Anchors perpendicular to the apparent direction of the strata.
- Bisectrix anchors, between the parallel anchors and the horizontal projection of the perpendicular ones.
- Bridge anchors horizontal and parallel to the direction of the strata, supporting the bridge in the adjacent strata.

Three types of extraction tests were done to determine the capacity of the anchors. The first one consisted of applying a tensioning load instantly. For the second test, a load was applied 24 hours later, and for the third a load test 15 days later.

Instant extraction tests were applied to six anchors not parallel to the apparent direction of the strata per the following:

- Tensioning to the design force (56.3 tons) for one minute.
- Discharge of up to 20% of the design force (11.3 tons), retaining it for one minute.
- Tensioning to 1.4 times the design force (78.9 tons), retaining it for three minutes.

- Differing extraction tests carried out for twelve anchors as follows:
 - Tensioning of each anchor to the design force, and recording the force variation after 24 hours.
 - In the anchors a test was carried out for the strata strength. This was done with a force 1.2 times higher than the design force.
 - In two perpendicular anchors a recording for 15 days was made to evaluate possible influence of clay compressibility in the joints of the strata on the prestress in the anchors.

The results for the instantaneous tests showed that a tension force 1.4 times the estimated design force, being maintained for three minutes, revealed no sliding of the anchors. The minimum embedment length used for all test anchors was 4.0 meters, and applying a 1.5 safety coefficient gave a required embedment length of 6.0 meters.

Regarding the 15 day tests, a 1% loss was observed and it was considered normal. These tests were performed in a direction perpendicular to the strata in order to observe the clay's compressibility influence on anchor force.

In summary, we can be assured of the absence of differing effects on the individual anchors. Thus it was recommended to anchor the structure to the rock mass by using dywidag type bars which are 32 mm. in diameter, 6.0 meters in embedment length, and 56.3 tons in capacity.

Structural Solution.

Based on the results of the previous studies it was decided to design such a structure that could protect the track and trains from rock falls. For this purpose a false tunnel was decided on. The tunnel would be supported by cantilever floor beam "knives" anchored to the rock in a transversal direction, along with direct supports to the ground.



Knives supporting "El Pensil."

The viaduct-tunnel "El Pensil" structural support is by 9 prestressed concrete "knives." Five of them are fixed to the rock mass by means of posttensioned anchors of low capacity (56.3 tons), with a fan-shape distribution to both the ground and elevation levels to reduce the maximum tension concentrations in the rock mass.

The posttensioned anchors have the following characteristics:

- Prestressed steel threaded bar (dywidag type), with a breaking limit of $10,500 \text{ kg/cm}^2$, which facilitates its installation, eliminates wedging losses, adds rigidity, and allows for permanent tension adjustments.
- Anchors are a double corrosion resistant type. Since they are permanent ones, they should stand possible water and humidity changes in the inner part of the rock mass which could cause corrosion under tension.

Finally, "knives" number 2 and 4 required 28 anchors each. "Knife" number 3, 20 anchors; number 5, 40 anchors, and number 6, 30 anchors. The anchor distribution to fix the "knives" to the ground is in a fan-shaped fashion with a ground level opening of $\pm 15^\circ$ around the normal opening to the layout of the track, passing through the axis of the "knife" with elevation angles 0° , 15° , 30° and 45° down to the horizontal.

Each of the eight modules of the superstructure is made of a reinforced concrete slab, with concrete strength of $F'_c = 250 \text{ kg/cm}^2$. The modules are poured on two prestressed concrete beams that are 15 meters in length with $F'_c = 400 \text{ kg/cm}^2$.

The vault is made of 60 cm. thick reinforced concrete. On the river side the vault is open arched, being supported on the ends of the "knives." On the mountain side the vault is supported on a rock mass by means of a footing, and in some zones it is supported by prestressed anchors like the ones described for the "knives."

Analysis Criteria

Next, we describe the calculations for each one of the elements that make up the structure:

Support "Knives."

For calculating the "knives," a subdivision was made for each of them using a finite element model. The loads generated by the superstructure and vault for live and dead load, together with the weight of the "knife," were considered in these models. Then with a computer program the stresses for different elements were determined in which the structure had been subdivided. Concrete strength was $F'_c = 350 \text{ kg/cm}^2$. Once the results of the stresses were determined the necessary prestress was assessed. Its effect on the model, as well as those stresses caused by external loads, defined the total stress to which each "knife" or support bracket was subjected.

Vault.

The calculations for the concrete vault, with $F'_c = 350 \text{ kg/cm}^2$, were made in a similar way to that for the "knives" using a finite element model. The loads and thrusts of the ground were applied to the model. Once the study for the different combination of possible loads was completed, including a study of seismic effects, the stresses and mechanical elements for each of the zones in which the vault was divided were obtained. Based on the results for each model, the vault and foundations were measured and built for both the rock mass side and also for the embankment side.

Viaduct-Tunnel Panel.

For calculating the viaduct-tunnel panel, one out of eight panels that make up the structure for track support, ballast, etc. was taken. It was considered as a special section to which the corresponding loads of the Cooper Type E-72 were applied, thus governing the design.



Interior of vault on "El Pensil."

Based on the above mentioned analysis, it was verified that all the beams could be built of the same length, obtaining their mechanical requirements and necessary prestress. The characteristics of the prestress were introduced in the structure model to increase its effect to the external reactions. In this way the total stresses applied to the structure were obtained, making sure that it was within acceptable limits.

Similar to the mechanical elements, calculations for the necessary reinforcement of the beams and slabs was carried out.

Based on the reactions obtained in the analysis, the support mechanisms were measured, checking the corresponding movements due to temperature, flow and contraction of the structure.

Construction Procedure

Postensioned Anchors and Anchorage Blocks.

The construction procedure for posttensioned anchors was as follows:

- 1) 4" boring for the insertion of anchors.
- 2) Placement of bar guide ducts that had been previously cut and prepared.
- 3) For the bars placement in a rugged plastic pipe was first done in a workshop. The pipe was then injected with a grout. The grout, together with the pipe, make the so called double corrosion protection to the anchor.
- 4) Placement of anchors inside the rock mass.
- 5) Secondary grout injection, using a stabilizing volume additive to form a bulb, by means of the injection hose.

Next, the pouring of the anchorage blocks and placement of steel plates for distribution of the loads was done. After the poured concrete blocks acquired strength each bar was tensioned with a 59 ton force. The bars were then tensioned and a third grout injection was performed. This was known as the sealing operation.

Prestressed Concrete "Knives."

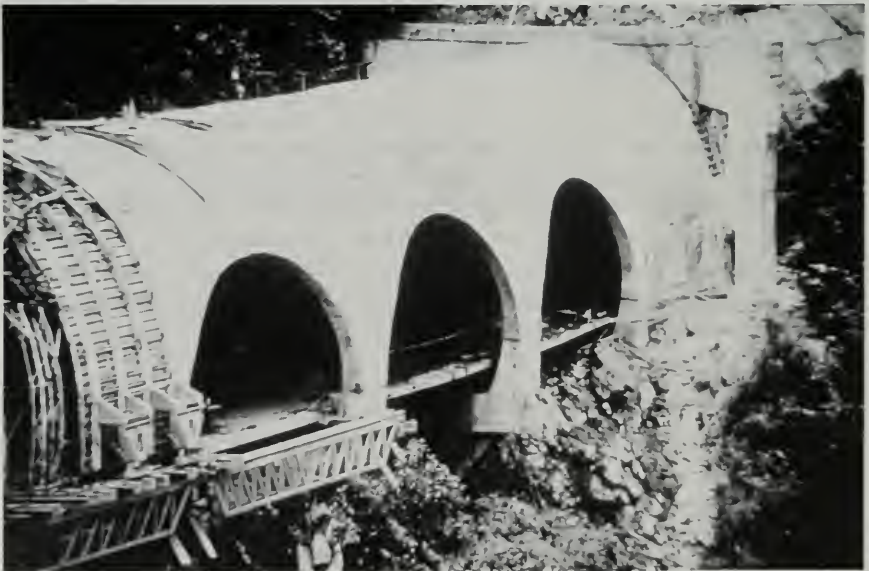
In pouring each "knife" the corresponding anchor to the ground had already been tensioned and it was then necessary to control the rock excavation to avoid affecting the compressed rock. On the other hand, the connection or overlap between a knife and its anchorage block has very significant shearing stresses. Because of this it has a bar prestress which guarantees the maximum rigidity and minimum wedging losses for these 4 to 5 meter long bars. Prestressing of the "knives" is done through traditional posttensioning.

Prestressed Concrete Beams in the Panels.

Beams 15 meters long were manufactured once the "knife" construction had been completed. The two beams required for each section were poured on site. The beam on the river side was poured in the position of that on the side of the mountain. Then it was put in place by moving it transversely on the support "knives" using hydraulic jacks supported on concrete anchorage.

Reinforced Concrete Slabs With Premanufactured Sidewalks and Curbs to Form the Ballast Deck.

A reinforced concrete slab was poured on the beams. They, together with the reinforced concrete sidewalks and curbs were used in receiving the ballast and the track. The construction of sidewalks and curbs in 2 meter sections allowed for better finishing and quality, given its special transversal section, thus saving construction time.



Pouring the vault for "El Pensil."

Vault.

The support of the vault on the mountain side was by means of a continuous footing. Its excavation had to be controlled to avoid damage to the precompressed rock mass. In some zones the vault is anchored to the ground with postensioned bars (a total of 20), all having the same geometrical characteristics. They were placed the same way as the "knives," and have the double corrosion resistant protection.

For the pouring of the vault, and to achieve the appropriate finishing, special metal arch centering was used. The metal mold, approximately 5.0 meters in length, allowed for the division of 15 meter clearances into three chords. The structure is located in a horizontal circular curve which permitted more use of the arch centering.

The equipment or elements that constituted the metal mold may be summarized as follows:

- 1) Interior arch centering.
- 2) Exterior arch centering.
- 3) Conveyors or frames for support and transporting.
- 4) Horizontal curve adjustment panels.
- 5) Support elements for the arch centering.
- 6) Arch centering for exterior arches.
- 7) Anchorage system.

Filling Between the Vault and the Mountain.

In order to absorb possible rock falls from the highest part of the mountain, and to ease the thrust of the blocks at the vault, all the space between the vault and the mountain were filled with granular material. A filtration and drainage system sends part of the water through the base of the vault and the surplus parallel to the vault itself. Drainage is then to a point on the viaduct where there is a portal wall with a same sized drainage system.

RECONDITIONING WORK ON THE CHIHUAHUA-PUERTO TOPOLOBAMPO ROUTE

By: Ing. Juan Antonio Siordia Rivera* and Ing. Fernando Osorio Rodriguez*

Background

The railroad route that goes from Chihuahua in the state of Chihuahua to Puerto Topolobampo in the state of Sinaloa on the coast of the Pacific Ocean, where the Cortez Sea is located, has become a potentially important route. It will attract freight traffic to and from the Asian Pacific to the north and northeast parts of the Mexican republic, central and eastern United States, and southeast of Canada, which was the intended purpose for construction of this line.

It is important to mention some advantages on this route. For example, time and distance can be reduced by taking the Topolobampo-Houston route instead of the Long Beach-Houston route, a reduction of 451 miles. In fact, there is not a shorter distance between west and east in the United States, by either land or sea, than the Topolobampo-Chihuahua-Ojinaga route thru the Mexican territory.

As mentioned in other papers this route has 88 tunnels with 11.1 miles total length, and 218 bridges totalling 4.3 miles. A great difference in altitudes exists along the route. The highest point is Sanchez station in the state of Chihuahua at 8,015 feet above sea level, whereas the Topolobampo port is at sea level. The route goes down the Septentrional part of the West Sierra Madre, across mountains and beautiful valleys.

In such an environment the work that has been carried out to recondition the "Q" line has been a challenge for our company. In spite of its natural beauties and cultural characteristics that can be observed during our trip by train, it always meant serious obstacles for the execution of railroad work.

Track Rehabilitation Work

In 1961 the Chihuahua-Pacific route was inaugurated. The track was built with ARA-A 90 lb/yd rail on biblock concrete ties with an elastic fastening system. This was one of the first lines in Mexico which had elastic fasteners, but over the years construction of this type of track has been increasing throughout the national railroad system.

As time and traffic passed on this line the rails have had various internal failures. These failures have been detected by the Sperry car, which is annually rented by us to check the integrity of the rails. As a result of the inspections in 1980, reconditioning work began to change out the defective rails for a heavier rail, i.e. 115 RE. Furthermore, the original biblock tie was having failures. The main problem was separation of the steel bar between both blocks, which caused problems in adequately keeping the geometry of the track. These ties are being replaced with I-84 monolithic posttensioned concrete ties.

From the beginning, rail replacement has been focused on the critical zones of the line, where curvature presents a main cause for the rail and tie to fail more rapidly. In 1980, rail replacement began between San Andreas, Chihuahua, km. Q-365, and Agua Caliente, Sinaloa, km. Q-774, which meant a 409 kilometer rehabilitation. Between 1991 and 1992 there have been two work stations utilized to replace the rail. The first one from km. Q-365 to Q-319 to the north of San Andres, Chihuahua, and the second one from km. Q-774 to Q-800, south of Agua Caliente. This represents a rehabilitation of 72 kilometers in length. We are currently replacing rail and the biblock tie to a monoblock type between km. Q-316 and Q-268 north of Santa Isabel.

All of this work has been done by our own personnel using mainly hand operated systems. However, 78' long welded rails have been prepared previously in stationary welding plants which reduced welding work in the field.

For the rehabilitated stretches made during 1991-1992, joint bars on the long welded rails are being removed by electric field welding, using mobile Holland welding machines.

*National Railways of Mexico

Line Complement to the New Puerto Topolobampo

Topolobampo, a natural port in the Mexican Pacific, compares to that of San Francisco, California. As a point, it was a must for the line to the west that would allow the shortest route to and from the Asian east, linking the central and eastern part of the United States. We should remember that at the turn of the century during the planning of this route the Panama Canal did not yet exist. In the beginning the line used to end in the old port of Topolobampo, which was built in the 1940's with an infrastructure that met the needs of that time. However, as the population grew around the dock facilities, and trade development in the region rapidly increased, these facilities became insufficient. As a result there was a need to build a new infrastructure to meet the demands, using a different outlook than required for the original port.

In 1991 the first stage of the new high capacity Topolobampo seaport was completed. It was equipped to receive container and grain ships of up to 50,000 tons of dead weight. It has modern and efficient equipment to handle fishing, agricultural, mineral, and industrial products. Following are some of the services provided by the port of Topolobampo:

- An operational side dock 240 meters in length, 216 meters in width and 12 meters in depth.
- Storage for containers with a surface area of 12.7 hectares.
- Warehouse and shed facilities of 4,500 square meters and 300 square meter office buildings.
- 4 lane road access 7.5 meters wide in each direction, with dividing windrow of one meter and a 2 meter road shoulder.
- Water is supplied from the Miguel Hidalgo and Josefa Ortiz de Dominguez dams so that industrial requirements are guaranteed. Furthermore, a waterworks plant having a 120-liter per second capacity is there.
- Power is supplied by a thermoelectric plant with 41 megawatt capacity. Also, the nearby hydroelectric plant at Miguel Hidalgo Dam is capable of supplying 60 additional megawatts.
- Fuel supply comes from Pemex's sea depot which has a 1,150,000 barrel storage capacity.
- For a start, 300 hectares are planned for industrial development, and this area can be expanded.

As one of the connections to the new port Topolobampo, 7.5 kilometers of track between the port and the Chihuahua-Pacific railroad were built. Near the dock there is a yard with 10 tracks for receiving, classification and shipping of freights. The track was built using ARA-A 100 lb/yd jointed rail on monolithic posttensioned concrete ties. This represented a \$5,200,000 US dollar investment.

Maintenance on Bridge Supports

Until 1987 the line was part of the Chihuahua-Pacific Railroad. At that time, the company National Railways of Mexico merged becoming one single company nationwide. The former Chihuahua-Pacific Railroad did not have trained personnel to do the specialized repair work required on bridges. After the merger skilled riveting gangs for repair of defective bridges were available as of 1989. Correction of supports in several bridges, both steel and concrete, were scheduled. These supports were vertically misaligned due to large temperature changes taking place in the range between 5°F and 104°F. As soon as these defects were detected the bridges were temporarily protected using wood blocks. The job then done by the riveting gang consisted of the following activities:

1. Whenever possible the vertically misaligned movable bearings were realigned. The structure was elevated using jacks and position of the bearings was corrected.
2. When it was not possible to align the movable bearings due to lack of space to jack the structure, or because of its heavy weight, metal braces were made and placed next to the misaligned movable bearings to protect the structure in case of bigger deformations due to temperature changes.

Reinforcement on the Agua Caliente Bridge

The most important bridge on the line is the one located at km. post Q-779 + 500 that crosses the Fuerte River. The river originates from the rain and thawing in the West Sierra Madre, where in the lower part it provides water for the valley. It is a very important source of irrigation for crop production in this zone and for the rest of the country.



Bridge over the Fuerte River at Km. Post Q-779 + 500.

This bridge at the north end is 3 open deck warren trusses with riveted connections; two trusses are 236', and one 295' in length. Each truss is 34'7" high. Seven girder spans, 106'7" in length and 8'10" in height are on the south end. As a whole the bridge is 1,526'7" in length. The bridge is supported upon masonry abutments and reinforced concrete piers with a total height of 164'.

Since its construction in 1961, with a calculated Cooper E-50 load design, the bridge structure has not been upgraded. In 1989, the current bridge capacity was analyzed and its reinforcement was calculated for E-80 Cooper capacity. By installing a reinforced ballast deck, thus eliminating the risk of fire on the previous wood cover, the impact effects on the bridge were diminished. As of July 1989 the integral reinforcement work on the superstructure was contracted. The system to be employed was the addition of steel plates and structural members to form box sections for truss elements. A total of 363 steel tons and 1,750 linear meters of welding were used in the reinforcement. As a complement, an anticorrosive protective coating was applied to the 12,500 square meters of the structure. The cost of the above mentioned repairs was \$570,000, and the work took 16 months to be completed.

Based on a previous study it was determined that the substructure of the bridge required no reinforcement work whatsoever despite its slim piers. Repair work was done simultaneously on the bridge caps since some of them had small cracks in the support area. This problem was solved with epoxy resin injection used in repairing the damaged areas.

Placement of Reinforced Concrete Slabs on the Agua Caliente Bridge

As mentioned previously, the Agua Caliente Bridge across the Fuerte River at km. Post Q-799+500, 1,526'7" in length, had its superstructure reinforced along with needed pier repairs. Modification of the bridge deck was planned, to be changed from an open deck to a closed one utilizing reinforced concrete slabs.

Construction of the 145 slabs used for the decking was done by contract. All of them were poured in the City of Chihuahua, and later they were transported to the bridge. They were designed for E-80 Cooper capacity to harmonize with the capacity of the metal superstructure which had just been reinforced. The slabs were made in modules of 10'6" in length so they could be handled easily with equipment that the

National Railways of Mexico has, since installation was scheduled to be done by company personnel. One basic advance operation carried out for slab deck installation was the track preparation of cutting rails at uniform sections to retire complete modules or "track panels," making dismantling easier. In coordination with the transportation and traffic departments, a date for substitution of the wood cover for the slabs was arranged for March, 1992. The procedure to be followed was two simultaneous work sites were set up with one site on each side of the bridge. Work personnel starting from the center of the bridge retired one by one the track panels that had been formed. They then mounted one by one the reinforced concrete slabs until mounting of 145 slabs was complete. At the beginning of work, after 4 slabs were placed on the bridge, they were anchored to the metal structure through holes specially designed for this purpose. Once the mounting and the anchorage of the slabs was complete, track laying, as well as ballasting, leveling, and alignment followed. 115 lb/yd rail was installed in replacement of the existing 90 lb/yd rail, being laid on I-84 monolithic posttensioned concrete ties.

This is the first time on this line in which concrete slabs have been placed on steel trusses, but the decision to install them is based on the success and benefits that similar works have reported on other lines of the national railway system.

Reinforcement of Other Steel Bridges on the Line

We are aware that the stretch between Chihuahua and Topolobampo is the most important one on the "Q" line. Since last year reinforcement of 19 steel bridges located between Chihuahua and Pichachic was scheduled. Eventhough they are not as important as the one in Agua Caliente, they had low capacity according to current and future demands on the initial portion of the line.

Reinforcement work was contracted to not interfere with the traffic of trains. Two bridges had through girders and 17 bridges had open deck girders. Basically the work consisted of the addition of structural steel plates, mainly in the flanges of the steel beams. In some cases girder webs were reinforced to absorb shearing stresses. To protect the bridges anticorrosive paint was applied to all of them upon completion of the reinforcement.

Construction of the "4 Vientos" False Tunnel

During construction of the Chihuahua-Pacific Railroad at km. Post Q-590 there was a modification to track alignment. Initially, it was intended to build a tunnel on the right side of the current line, however, because of unstable rock strata at this point, the alignment was moved to the left. Cutting to the rock had to be done, 459' in length and 148' in maximum height, resulting in steep vertical walls. In some sections it resulted in water leakage through the cutting and freezing in the fissures in the winter. Over the years the



Entrance to "4 Vientos" False Tunnel.

presence of unstable zones have been detected. Since 1980 the safety of train operations has been diminishing. Some landslides occurred in the area and this situation worsened so much that it was necessary to establish a constant inspection on this cut, 24 hours a day. A permanent slow order was issued to reduce the speed of trains in the zone.

Because of this situation several studies were made to define the best and most cost effective solution for providing safety in the area. Based on this study it was decided to build a false tunnel, 360' 11" in length, to be constructed of masonry walls with a reinforced concrete cap to support the voussoirs that would make up the tunnel vault. During construction, use of sliding arch forms was not considered because it would represent a hinderance to the operation of trains.

Construction work for the masonry walls was initiated with railroad personnel in 1990. Later on, it was completed through a contract for the continuation and finishing of the masonry work. The contractor, to avoid falling rocks when putting up the walls, integrated the cut rock to the walls when possible. Because of the difficulty in accessing materials, rock from drilling the first tunnel that was intended to be built was used for the walls. The reinforced concrete voussoirs were totally made in the city of Chihuahua to achieve better quality control. Since the projected tunnel was located on a curve, the voussoir had to be made taking into account the difference in exterior and interior lengths of the supports. Once the voussoirs were finished they were taken to the field and their mounting was scheduled. Installation was combined with the colocation of an earth fill, 6'7" in thickness, on the superior and external part of the tunnel in order to protect it. This earth fill was made of fine waste material from the rock used for the walls so that it would absorb the impacts from possible landslides of rocks in the future. As complementary work, the ditches were coated with concrete along the cutting in order to provide good drainage.

During the design of this false tunnel we considered the clearance necessary for 20' double stack trains due to an increase in demand for this type of train in the future. The work took 15 months to complete and we will see it on our trip to Topolobampo.

Enlargement of Clearance in Tunnels for Short Double Stack Trains

Out of the 88 existing tunnels on the line, 60 have restrictions to 20' double stacks, and 17 of them have restrictions even for the 18' shorter double stacks.

Since our budget has hindered the performance of an overall enlargement of all tunnels, we had to look at those requiring minor alterations so short double stack traffic could be accommodated. As of June 1990 work began with company personnel. The purpose was to eliminate rock outcropping found in tunnels which would hinder the traffic of short double stack trains. Through these tunnel



Viaduct-Tunnel "El Lazo (The Rope)" at km. Post Q-592 + 624.

corrections, amounting to two months work, there now exists the capability to handle more modern loads which have been gradually introduced.

Future Reconditioning Work

One of the most remarkable constructions on the line is the viaduct-tunnel called "El Lazo" ("The Rope"), located at km. post Q-592 + 624. It is a viaduct with a masonry arch through which the track goes down to a curve of 360° . Over the years, and because of the weathering characteristics of the cut underneath the viaduct, this area has been developing fissures that are a major concern for the safety of train traffic. This year necessary work to protect the cut began. In order to do this the tunnel is being expanded to totally go underneath the viaduct. We will then have a stretch with a false tunnel, just like the tunnel "4 Vientos" ("4 Winds") described above. It will serve to protect not only the cut walls but also to limit the amount of cut that supports the viaduct. Additionally, masonry paving will be built in the support zone of the viaduct to channel the drainage that goes to the extension of the tunnel.

Another relevant work is the international Ojinaga Bridge. It is made of steel and timber stringers in the superstructure, and timber trestles for the substructure. Total length of the bridge is 410' with a maximum height of 26'. Seventy four meters of the bridge are on the Mexican side and 51 meters are on the U.S. side. This bridge was not a strategic line but now this line is acquiring more importance. Several failures of the bridge have been detected. The latest failure was in September 1991 due to a heavy rain. It was decided to reconstruct this bridge, at least on the Mexican side, and it will be modified using prestressed concrete pile bents and prestressed concrete girders so that it becomes safer for the traffic increase expected in the near future.

There are two steel viaducts which are very important on this line, at km. posts Q-359 + 375 and Q-363 + 700. So far there has not been any significant repair work done, though it is needed to some extent. However, studies are being made to evaluate the convenience of reinforcement work on the structure. The idea is to maintain the viaducts or build embankments where only minor work is required to handle any drainage. This way there would be significant savings for maintenance required for such important and delicate structures.

Apart from the "Agua Caliente" bridge at km. post Q-789 + 500 mentioned before, there are two other bridges of unique importance because of their open deck warren trusses, both with characteristics identical to those of the first bridge mentioned. These bridges are: "El Chinapas" at km. post Q-749 + 000, and "La Cascada," km. Q-745 + 000. The former bridge is the highest, 335' in height, and is 786' in length. These bridges have not been reinforced as in the case of the "Agua Caliente." It is estimated that their reinforcement will begin in about two years. Another objective during bridge rehabilitation is to reduce fire risk. This will be achieved by covering all the steel trusses on this line with steel reinforcement. We will see the two bridges mentioned on our train trip.

Currently, 88 tunnels have the capacity to take the short double stack trains. However, a short term objective is to increase their clearances so that all accept the 20' high double stacks. To accomplish this it is necessary to work on the 39 tunnels distributed along the whole line. For bridges, all together they are 6.13 miles in length. Clearance in the bridges has to be enlarged, and most of them reside in curves. We have the tunnel called "La Pera de Chicural," which is on a grade and makes up a curve of practically 180° and 3,084' in length. Also, the tunnel "El Descanso," the longest on all of this line is 5,968' in length. These two tunnels make up 28% of the total length of tunnels to be enlarged.

Conclusions

As it can be seen in this paper, reconditioning work that has been done on this route since 1967 has been many and varied. All of the work has one thing in common: the difficulties associated with their location, since the altitudes required for the line are extreme in order to achieve the shortest route to the Pacific. However, these challenges have been overcome using a great deal of imagination and dedication with limited economic resources. There is still a lot to do, but it will be done, not only looking to the most modern techniques available, but also keeping in mind the fundamental objective of making our transportation system a more efficient one. During our trip to Topolobampo we will see the work described here. Thank you very much.

FAST HEAVY AXLE LOAD PROGRAM UPDATE

By: R. P. Reiff* and M. C. Trevizo**

This presentation is an update on the effects of increasing axle loads on conventional and improved track components.

FAST BACKGROUND

The Facility for Accelerated Service Testing (FAST) program at the Transportation Test Center, Pueblo, Colorado, has been in operation since late 1976, accumulating well over 1 billion gross tons of traffic on various configurations of a closed loop. A significant data base on the response of conventional track materials has been gathered and published in numerous technical reports, as well as presented in a number of technical sessions.

The original FAST program was operated with conventional freight car equipment, using standard three-piece trucks and 100-ton capacity equipment. The consist for the first 11 years was made up primarily of 100-ton capacity cars of a standard design, with occasional introduction of cars with self-steering trucks, along with TOFC, tank and other non-bulk commodity equipment for short test periods.

In 1985 funding for the FAST program, which had been solely provided by the Federal Railroad Administration (FRA), was supplemented with Association of American Railroad (AAR) funds. As FRA funding was gradually being reduced over the ensuing years, AAR funding was increasing. Presently the annual FAST operating budget is equally shared between FRA and AAR. It should be pointed out that the railroad and supply industry contribute a significant amount to the program as well, in the form of donated/loaned equipment, materials and technical personnel.

The last 160 MGT of the 100-ton car era on FAST was conducted from 1985 to 1987. This introduced the shorter High Tonnage Loop, which was constructed in an effort to reduce costs and make FAST become more efficient in the application of MGT's. This last 160 MGT, using a consist of entirely 100-ton capacity equipment, became the "baseline" for comparison purposes when the axle load was to be increased.

In 1988 the FAST train was reconfigured to a heavier axle load, using what was considered at that time to be 125-ton capacity equipment. The axle loading, per car, increased from 33 tons to 39 tons. Subsequently, an identical 160 MGT comparison period was operated, where track experiments conducted during the last 160 MGT with 33-ton axle load equipment were repeated as closely as possible. Data was carefully collected and analyzed during these two periods.

Each 160 MGT period was operated over essentially the same track components, using the same maintenance techniques. Results provided insight into the effect of increasing axle loads on existing track structure.

RESULTS OF INCREASED AXLE LOADS

Results reported at the October 1990 Workshop on Heavy Axle Loads, Pueblo, Colorado, indicated that heavier axle loads could be operated over conventional track, but that more rapid and severe deterioration would occur. Areas showing the most immediate impact included rail, turnouts, welds, and spot maintenance. Other areas of the track indicated possible effects, but could not be adequately defined in the limited 160 MGT period. Therefore, the FAST program was extended to determine the effects of heavy axle loads for these areas, which include rail grinding, track support/maintenance, wood ties, concrete ties and ballast. Improved components also are being evaluated where a definite impact from heavy axle load (HAL) traffic was noted. Advanced design turnout geometry, frog materials, improved field welds, various rail metallurgies and heat treatments, and monitoring of subgrade loads under a variety of support conditions are included for the components tests.

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New areas of investigation, such as concrete tie rail seat abrasion, observed on revenue service lines with heavy traffic, and the loads on crossing frogs were added.

Initial results of the concrete tie rail seat abrasion investigation showed significant influence of different concrete mixtures, repair techniques and pad material on the amount and rate of abrasion. The life of a crossing frog of conventional design and material was evaluated and found to be significantly reduced under heavy axle load.

The ongoing FAST/HAL operation is evaluating a number of improved track components and maintenance techniques necessary when a large percentage of HAL traffic is to be operated. Results of the first 160 MGT experiment gave us an indication as to where the track structure must be improved. The supply industry was quick to respond with a host of higher quality products. Testing at FAST shows us how research results conducted in a controlled environment can be used to improve the materials used in tracks.

The following is a summary of some of the findings presented at the FAST Open House held September 15 and 16, 1992, in Pueblo, Colorado.

Rail strength continues to be an important issue. Data indicates that rail 300 Bhn or higher is necessary to reduce metal flow and corrugations on tangent track. In special track work, such as turnouts and crossing frogs, a 340 Bhn or higher strength rail is mandatory, otherwise the result will be a severe and rapid degradation of the running surface. Curve track also shows a need for rail of 340 Bhn or higher to resist wear and metal flow.

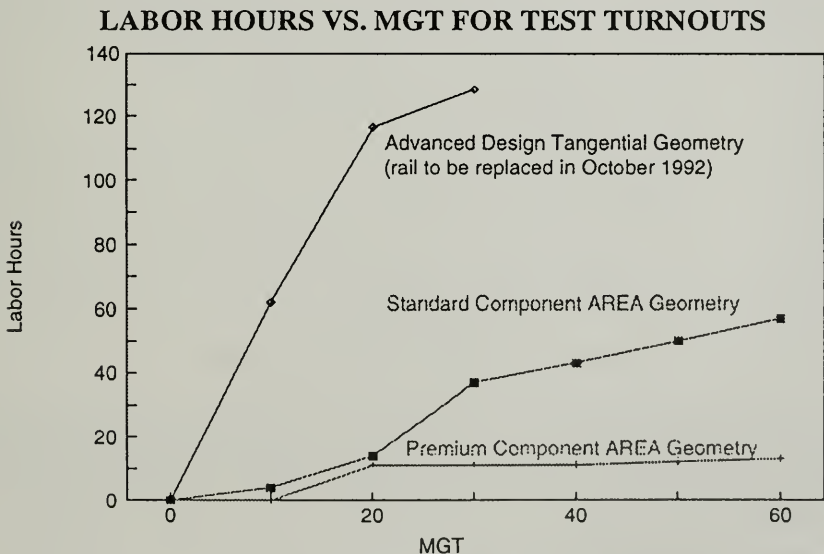


Figure 1. Maintenance manhours from turnout test.

Turnouts continue to be a high maintenance area. The spring frog installation indicated a very high maintenance demand when compared to that of traditional rail-bound manganese frogs. The advanced design turnout did reduce loads into the track structure; however, the use of rail with insufficient hardness resulted in higher than desirable maintenance efforts.

Use of premium thermite field welds, instead of standard materials, which suffered a significant increase in failure rate during the initial phase of HAL, indicated lower failure rates. Field weld failures are still an issue as they continue to show relatively short lives. There are, however, some techniques and materials that appear to extend life, even though training and quality control of field techniques continue to be a critical issue.

In the area of conventional wood ties and fasteners, the cut spike continues to show more degradation than direct fixation/elastic fasteners. Also under the FAST environment the difference between conventional hardwood and softwood ties is small when strength is compared. Softwood ties, however, show more permanent gage widening than the hardwood ties.

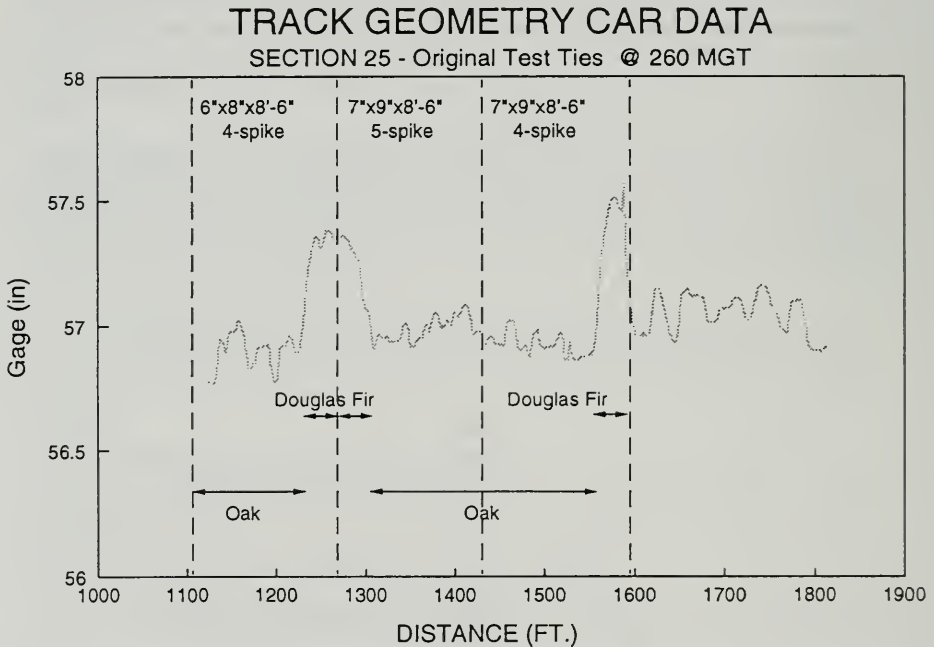


Figure 2. Gage widening of ties with cut spikes.

Finally, track support conditions show a dramatic effect on maintenance demand. The FAST loop is constructed on a stiff subgrade and has shown little increase in demand for out of face surfacing with the introduction of HAL traffic. In the area where the support condition was made intentionally soft, maintenance demand skyrocketed, indicating possible concern where HAL traffic is contemplated over areas of marginal track support.

FUTURE

Continued MGT application is scheduled until 1994, at which time the present consist will be upgraded. New and improved components, which are designed to better withstand the rigors of the HAL environment, will be cycled into the FAST track for evaluation when they are offered and track space becomes available.

To date, all 33- and 39-ton axle load traffic has been applied using conventional, standard-three piece freight car trucks. The HAL train is essentially 100-ton type equipment "scaled up." This includes larger

VERTICAL WHEEL FORCE INCREASE IN LOW MODULUS TEST ZONE

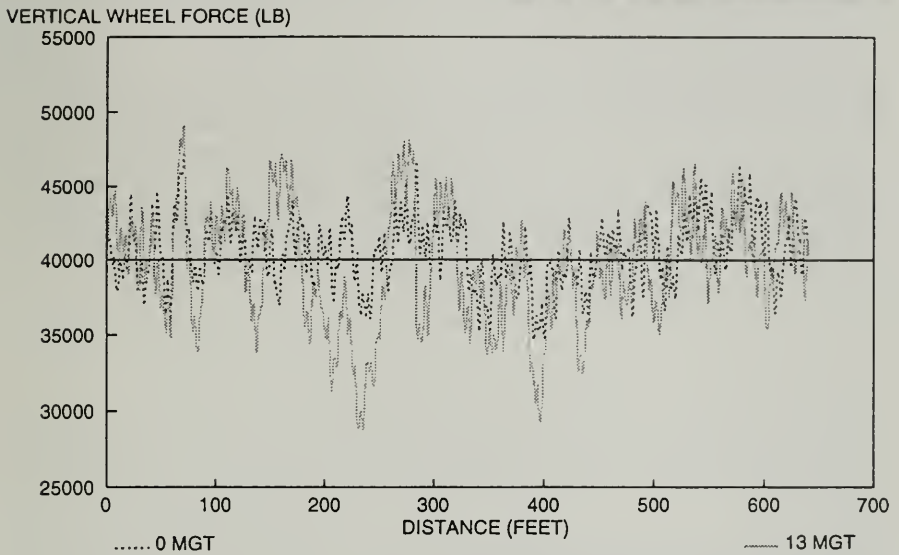


Figure 3. Soft subgrade site wheel force measurements.

CROSSLEVEL DEGRADATION COMPARISON

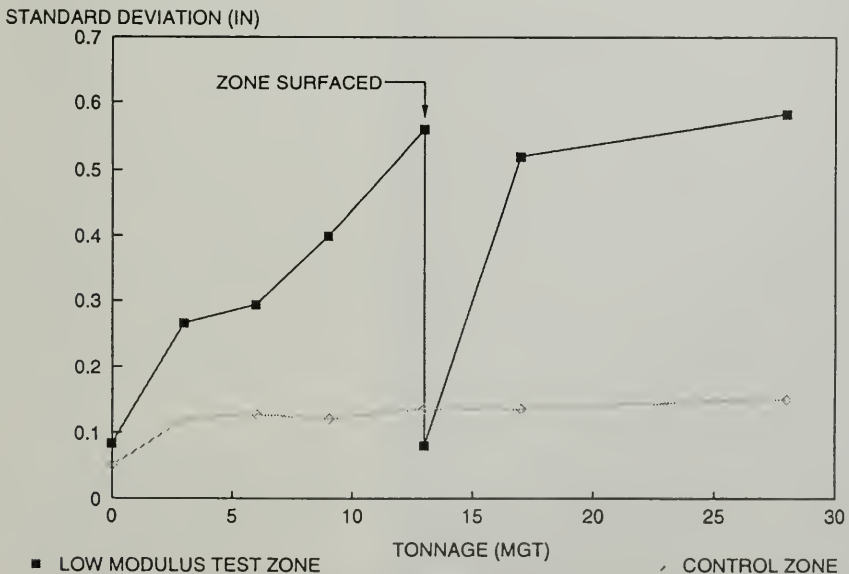


Figure 4. Comparison of standard and soft subgrade cross level degradation.

bearings, wheels and reinforced car bodies. However, there has been no change in suspension design from conventional equipment. The resulting dynamic loads into the track have been shown to be quite high, suffering in many cases from a basically unsophisticated suspension.

The future direction of FAST includes the complete replacement of existing trucks with those of improved design, but still supporting a 39-ton type axle load. The design of these trucks, several of which are currently undergoing evaluation, will reduce dynamic loads into the track structure.

The next phase of FAST, which is presently scheduled to start in late 1994, will repeat selected experiments on the track to determine the actual reduction in component wear, fatigue, and track maintenance, when a HAL train of "advanced" suspension is operated. Thus the present operation of HAL will become the new baseline for comparing future data under a train of superior trucks.

HISTORY AND CONSTRUCTION SUMMARY OF THE CHIHUAHUA TO THE PACIFIC RAILROAD. OUTLOOK FOR THE NEW PORT OF TOPOLOBAMPO.

By: Ing. Ernesto Rivera U.* and Ing. J. Ruben Parra T.*

Background

In the late 1800's, men with transcontinental vision thought of the communication possibilities between productive populated villages with nearby ports; to establish international trade with no barriers via the sea. These visions are seen in today's current trends.

In 1879, Albert K. Owen wrote: "El oriente y el occidente, sinopsis de Los Esfuerzos que iia hecio el occidente para establecer comunicaciones comerciales con el oriente," which translates to "The west makes an effort to establish commercial communications with the east." In this essay, the importance of linking the central part of the United States with a Pacific port on the Mexican coast is discussed. Later President Diaz with Arthur Stilwell considered possible ways of linking the central United States and a Mexican port on the Pacific coast by the shortest route possible. This project became known as Kansas City, Mexico and Orient, or KCMO.

In 1897 location work began and the line section between Miñaca and Creel was built. The line section that goes through the Sierra's had been studied several times, which led to the establishment of 12 possible routes. In 1905, a route was selected by K.C.M.O. engineers which crossed the continental divide near Creel, continuing down in between the divide located in the middle of Barranca de Septentrion and Barranca del Urique, ending at the confluence with the Rio Fuerte. It then continued on through the Huites

Canyon and el Fuerte, San Blas and Topolobampo villages. This plan was completed by engineer Hardway in 1927. It had curves of up to 12 degrees and a maximum slope of 3% due to the ascents and descents in bridging the crest between Septentrion and Urique to reach useable ports. The construction work to complete this line was temporarily suspended in 1912 because of the revolutionary riots, and resumed again in 1942 under the National Railroad Program initiated in 1937. At this time the railroad traffic and tolls department of the Ministry for Communications and Public Works was created in order to handle the construction program following the revolution. In 1940 the study of the remaining line section was undertaken once again.

The Route

Engineer Francisco M. Tongo was in charge of finding a better solution for the uncompleted portion of the route. It resulted in a survey with curve designs of up to 9 degrees. By means of tunnels and viaducts,



Septentrion River in vicinity of planned railroad route.

*National Railways of Mexico

the maximum design grade was reduced to 2.5% for a section located in the basin of the hydrographic system of Rio Fuerte, which has as affluents the rivers Rio Chinipas and Rio Septentrion.

Between Creel and San Rafael, the line follows the continental divide with small counterslopes. Starting at San Rafael, Hardway's planned line location was abandoned and the line to Cuiteco was constructed by means of a tunnel. At a lower line location some necessary changes were made in order to preserve the grade—the first one in the Arroyo Cerocahui, and the second one in the Santa Barbara zone where the slope of the river is 4%. A large tunnel, as well as other small ones, were built. The orientation of the line was later revised by means of the Santa Barbara Bridge, resulting in a reversal of track of nearly 180 degrees. A 9 degree curve had to be used to accomplish this alignment. These modifications were the main ones introduced by engineer Togno to the Hardway plan, which substantially improved slopes and curves on the line.

There was another important modification to the interior portion of the original line proposed, since it was to be supported on the Huities Canyon at a height that ended up being too low for a storage reservoir of a dam of a hydroelectric plant scheduled for construction in this canyon. Because of this another tunnel was built near "El Descanso," and the line was routed by "Agua Caliente," crossing over the Rio Fuerte river.



Bridge Santa Barbara with 9° curve over the Barranca.

Construction Works from 1940 to 1958

On June 1940 the Mexican government bought the Kansas City, Mexico and Orient Railroad which had been built within the state of Chihuahua. After this acquisition the planning process for construction of the new section to be built sped up the location of the line, a final outline, and access road locations. Based on these roads construction camps and other sites were established. Also, a survey was conducted to solve the intersection of tracks with the Cuiteco, La Laja and El Fuerte Rivers.

In 1950, construction work on the mountain section was suspended. Only the maintenance and rebuilding work of sections already in operation were continued. However in 1953, the federal government decided to resume the construction work for the mountain section.

1953 is a cornerstone for the Mexican railroad industry. At this time the government purchased the Mexican Northeastern Railroad, which was incorporated into the Kansas City, Mexico and Orient Line. This in turn led to construction of the Chihuahua-Pacific Line.

From 1956 to 1958, investments and construction sites in different areas increased. Temoris, a new construction site located along one of the most rugged areas of the mountain was built. Access roads were connected providing an exit to the ocean. Meanwhile maintenance and rehabilitation work for line sections already in operation continued. Replacement of spiked track with elastic fasteners on wooden ties and installation of continuous welded rail were improvements made.

Construction Work Between 1959 and 1961

During this period of time construction work was extremely intense. The 248 kilometer mountain section located between Creel and San Pedro was built. Line sections in operation between Chihuahua-Creel (296 kms.), and San Pedro-Topolobampo (125 kms.) were rehabilitated. The whole section was inaugurated in 1961 linking the bordering city of Ojinaga and the Topolobampo port, a distance of 942 kilometers. Also, a branch from La Junta to the bordering city of Ciudad Juarez was connected.

General Aspects of the Construction Work

To understand the magnitude of the Chihuahua-Pacific work it is appropriate to mention the most important construction and reconstruction stages.

Access Roads

Because of the rough nature of the Sierra's it was necessary to utilize them as the backbone of the line to be built. Starting at a point on ends of the land line—Creel to San Pedro, the already established and various new construction sites required were given consideration. It was intended to, as much as possible, locate the access roads on the line planned for the railroad to lower costs, since the volumes excavated during access road construction would diminish the volumes to be dug at the time of building the railroad.

Also constructed were temporary and suspension bridges, as well as ferry bridges, for personnel to pass over plentiful rivers.

Earth Works

In the mountain section many varieties of rocks were encountered most of them volcanic—riolites, andesites, tufas and huge rocks surrounded by clay. In some zones the material is altered with geological faults. The way to perform each cutting and movement of earth to desired embankment was studied based on profiles, mass curves and cross sections. Prior to construction, drilling, excavation, and compacting machinery as well as an efficient supply plan were decided.

Drainage Works

Main and secondary drainage systems were important items because of the high volume of water to be carried off. Drainage work was completed before beginning the earth work, and these systems were protected against impacts by means of a layer of crushed stone. The main drainage system consisted almost entirely of masonry culverts because rocks are abundant in the region. On the other hand the culverts for secondary drainage are made of slabs or pipes of reinforced concrete.

In some cases it was necessary to build channel bridges which were made of reinforced concrete or masonry, providing clearance for the train, since it was not possible to drain the hillside by means of a drain under the track. The drainage system is complemented with ditches and counterdrains to guide the water and protect the complemented earth works.

Retaining Walls

It was necessary to build walls on the hillside where there were very acute transversal slopes, to protect the track from possible landslides.

False Tunnels

False tunnels were built in some deep cuts where taluses were unstable. A bed of soft material, 2 to 3 meters in thickness, was placed in the spaces between the tunnel and the cut to buffer the impact of landslides. Fourteen (14) false tunnels were built, but the most outstanding one is "Frankenstein" which is 200 meters in length.

Tunnels

The Sierra Tarahumara made it necessary to build not only a great number of tunnels, but also to make many cuts, bridges and viaducts. In this section 69 tunnels were excavated totalling an accumulated length of 13,817 meters. Together with those tunnels drilled beforehand, plus 14 false tunnels, a total of 87 are in the mainline. Because of their length the most important ones are: the Continental, 1,260 meters in length; the Carrizo, 775 meters; the Pera del Chicural, 937 meters; and the Descanso, 1,818 meters.

According to the preliminary study, tunnels that were determined as indispensable for equipment and supplies used in the construction works were drilled beforehand.

The construction procedure used was the so-called gallery advance. The middle superior section is excavated followed by the levelling and benching of the middle interior sections. The continental tunnel near Creel was the most troublesome. A pilot tunnel and pumping had to be resorted to in handling a continuous water flow rate of 100 liters per second.

Bridges and Viaducts

The great variety of mountain crossings, together with the geological characteristics of each crossing to open the way for the railroad, was a great challenge in the design of bridges and viaducts. However obstacles were successfully overcome thanks to the hard work and enthusiasm of Mexican engineers.

The construction of bridges was scheduled as much as possible in accordance with the general program used for all the construction areas. The total number of bridges built in the Sierra's was 32, amounting to an accumulated length of 3,229 meters. Abutments and masonry piers, cyclopean concrete, reinforced concrete, or concrete pipes were used for the substructures. Superstructures were made either of reinforced concrete, prestressed concrete, steel girders with a wooden or concrete deck prestressed steel girders or continuous trusses. All bridges on this line were projected for a Cooper E-50 live load.

Building procedures were of a varied nature. False truss methods were used to slide the concrete girders, and then to lower them to their supports with the help of sand jacks. As for the continuous girders, they were launched and supported during the process on the various piers. The trusses were mounted by parts: first the chords, and then the hangers and diagonals, immediately followed by the bracing in order to finish the mounting of the floor system. The main bridges are: El Chinipas with three sections of continuous trusses of 72, 90 and 72 meters having reinforced concrete and masonry abutments and cyclopean concrete piers. In the Fuerte Bridge there are 7 sections of welded steel at 35 meters each, and three continuous trusses of 62, 90 and 72 meters with reinforced concrete piers and abutments.

Trackage

Different studies were carried out to determine the weight of the rail to be installed. It was concluded that the 45 kg/m (90 lbs/yds) choice was the most convenient one. As for the type of track, the fastening chosen was "twice as elastic," and is widely known today. The track was assembled with wood ties in the Sierra section because of the abundance of this material in the region, as well as for curve strength reasons. For tangent track, reinforced concrete biblock ties were used. They were produced by a semimobile plant, which after having manufactured them in the Sinaloa Division, moved to the Chihuahua Division to continue the same kind of work.

Ballast grinding was done in selected banks along the line which conformed with established standards required for railroad ballast. For levelling and alignment of the track traditional methods were used, but of course with much less sophisticated machinery than the types used today.

Long rails up to 10 kms. in length were made using alumino-thermite welding. Track laying temperatures were controlled to control thermal stress and special rail expansion joints were used.

Before I go on with this presentation, I want to make a brief comment regarding the Indians from the Tarahumara Sierra. They can neither read, write nor even speak Spanish, but they were of great help in the construction of access roads and the track itself. Not even the cold snowfalls would stop them from working. We recall an event that occurred while unloading the rail at the Creel station with 3 feet of snow on the ground. When we asked the Tarahumaran Indians if they were cold, one of them who barely spoke Spanish answered "What do I want to be cold for if I don't even have a coat?" To all of them our respect and gratefulness for being the most loyal workers and friends in the mountains.



Bridge Chinipas over the river Septentrion.

The Reconstruction

During the construction period in the Sierra Section reconstruction of tracks in operation occurred. This work concluded some years later in 1961 after the inauguration of the mountain line section. In general terms, let us inform you that the drainage works were repaired; embankments were reinforced; temporary bridges were replaced with permanent ones; 362 kms. of spiked track was replaced with elastic fastener track on concrete ties; and 296 kms. of spiked track were replaced by elastic fastener track on wooden ties. The minimum rail weight was standardized at 90 lbs/yd.

Apart from this, various other modifications were made in the track. In order to improve alignment along the line, new yards and stations were built in Los Mochis and San Blas. At San Blas the new station was used for both the Chihuahua-Pacific Railroad and the Pacific Railroad since this is where two lines connect.

The total investment was as follows:

Construction of the mountain section	\$ 753,119,342
Reconstruction of the branch line	\$ 344,068,323
	\$1,097,187,648

At the beginning of this presentation I mentioned the people with a vision who had a brilliant idea of complementing sea transportation through continental routes, or the so called land links. Some of the most outstanding visionaries were Albert K. Owen and Arthur Stilwell who planned the line to stretch to the Pacific Ocean, and to link it with a natural port such as Topolobampo, a port currently undergoing extensive redevelopment. The one in charge of perfecting the project was an outstanding engineer and professor Francisco M. Togno.

Currently, North American ports on the Pacific are working to full capacity due to an increase of international freight, mainly from countries of the Pacific rim. Establishment of a short land link, such as the Ojinaga-Topolobampo one, could improve the steadfast and cost effective-handling of international cargo. Regarding this possibility, it is our pleasure to announce that officials from one of the most outstanding railroads of North America are negotiating with officials from Ferrocarriles Nacionales de Mexico. It is expected that this dream of a new connection will come true sometime during this decade.

Mexican technicians and workers made a major effort in completing the construction works mentioned here. This project was carried out decisively and enthusiastically because there is an urgent need in this country to rely on beneficial projects to provide better living standards in accord with the modern world.

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COMMITTEE 1 — ROADWAY AND BALLAST

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Commentary on the Design of Uncased Pipelines at Railroad Crossings

Subcommittee Chairman: R. J. Boileau

Subcommittee Vice Chairman: H. E. Stewart

ABSTRACT

This commentary summarizes research on pipeline crossings of railroads and a resulting, comprehensive methodology for evaluating stresses conveyed to uncased pipelines in such environments. The research was performed at Cornell University under the sponsorship of the Gas Research Institute with guidance from representatives of the gas and railroad industries. The commentary begins with a description of state-of-the-art reviews summarizing specifications of various professional societies and regulatory institutions, construction techniques, loading conditions at crossings, corrosion protection, and design practices. Next, the analytical methods used to evaluate pipeline stresses are described, with emphasis on the modes of pipeline deformation which need to be modeled in a comprehensive analytical approach. The design methodology, which was derived from analytical and field studies, is summarized in a topical report "Guidelines for Pipelines Crossing Railroads," prepared by the School of Civil and Environmental Engineer, Cornell University. Comparisons between the new methodology and conventional design procedures are made. Full scale field tests performed at the Transportation Test Center operated by the American Association of Railroads are discussed. These tests were undertaken to validate the design methodology under actual rail loading conditions. Field measurements are compared with the strains and stresses predicted by various analytical models. Guidelines pertaining to stress analysis and good practice at railroad crossings are discussed. Finally, the design parameters used to determine the tabulated values of wall thickness given in the AREA Manual of Recommended Practice are presented.

INTRODUCTION

When steel pipelines for gas distribution and transmission cross railroads, railroad companies often require that the steel carrier pipes can be installed within casings. This requirement is intended to promote safety and protect property and important routes in the event of a mishap.

In practice, there is significant doubt that casings enhance safety because the presence of a casing can reduce or eliminate the effectiveness of cathodic protection, which guards against subsurface corrosion. Casings may also result in gas pipeline exposure to atmospheric corrosion. Moreover, the introduction of a casing complicates the electrical system associated with cathodic protection so that meaningful corrosion survey measurements are often difficult to secure and interpret.

Considerable savings and improved safety can be realized if gas transmission and distribution companies pursue alternatives to casings. The elimination of a casing, however, raises legitimate questions about the levels of stress and deformation that affect a pipeline installed without the benefits of protective enclosure. The increased levels of load at railways lead to conditions of pipeline stress which are not addressed fully in current codes and recommendations.

Researchers at Cornell University were sponsored by the Gas Research Institute (GRI) to evaluate the stress conditions at railroad crossings and to develop and verify a design methodology acceptable to gas and railroad industries. This commentary reports the principal research results. The research followed a systematic and comprehensive plan which involved an evaluation of U.S. and foreign practice and performance records (O'Rourke, et al., 1986; O'Rourke et al., 1988; O'Rourke, et al., 1991b.), three-dimensional finite elements analyses (Blewitt, et al., 1987), and full scale field testing (Stewart, et

al., 1991a). Major results of the work consist of a Technical Summary and Database (TSD) and concise Guidelines for the design and installation of uncased pipelines crossing railroads (Ingraffea, et al., 1991; Stewart, et al., 1991b).

The paper begins with a description of state-of-the-art reviews performed to summarize the specifications of various professional societies and regulatory institutions, construction techniques, loading conditions at crossings, corrosion protection, and design practices. Next, the analytical methods used to evaluate pipeline stresses are described, with emphasis on the modes of pipeline deformation which need to be modeled in a comprehensive analytical approach. The design methodology, which was derived from analytical and field studies, is given in the topical report "Guidelines for Pipelines Crossing Railroads" mentioned previously in the Abstract. Comparisons between the new methodology and conventional design procedures are made. Full scale field tests performed at the Transportation Test Center operated by the American Association of Railroads are discussed. These tests were undertaken to validate the design methodology under actual rail loading conditions. Field measurements are compared with the strains and stresses predicted by various analytical models. Guidelines pertaining to stress analysis and good practice at railroad crossings are discussed.

STATE-OF-THE-ART REVIEWS

A state-of-the-art review was performed for pipeline crossings of railroads (O'Rourke, et al., 1986). These works focused in part on existing U.S. professional society recommendations and governmental regulations. In addition, practices in other countries were examined, and a review was made of the safety record pertaining to transportation crossings. A summary of existing practices helps one understand how current practices have evolved, and provides oversight related to the positions taken by different agencies. It permits a comparison among the practices advocated by different professional and governmental institutions so that areas of similarity as well as differences in approach can be identified. Finally, it allows one to understand the specific technical issues which have been addressed and to use these as the basis for refining and expanding our ability to resolve technical questions which remain unanswered.

U.S. Practices

Recommendations pertaining to natural gas and liquid fuel pipelines are summarized in Table 1. Table 1 is organized chronologically, based on the year each recommended practice was introduced. Also included in the table is a description of the relationship among a given recommendation, other recommendations, and the Code of Federal Regulations. Title 49, Part 192 and Part 195 of the Code of Federal Regulations provides minimum safety standards for the U.S. (Office of the Federal Register, 1990a and b).

It is interesting to note that most recommendations do not specify casings for pipeline crossings at railroads or highways. Only the American Railway Engineering Association (AREA) and American Society of Civil Engineers (ASCE) recommend casings at railroad crossings, with the exception of secondary tracks. Metallic carrier pipes were recommended at all railroad crossings only in the earlier AREA recommendations.

Foreign Policies

A review of foreign practices for pipeline crossings revealed interesting trends, as evinced by activities in Canada, the United Kingdom, and the Federal Republic of Germany. In all three countries, recommendations have been adopted to allow uncased pipeline crossings.

Recent changes in approach in the United Kingdom are especially noteworthy. British experience with cased crossings has shown corrosion of the carrier pipe within casings to be a problem. Uncased pipelines currently are the preferred means of crossing major motorways. The option to use thicker wall carrier pipes in lieu of casings at crossings was incorporated in the 1984 revision of the British Institution of Gas Engineers Recommendations (IGE, 1984).

Table 1. Summary Recommended U.S. Practices for Pipeline Crossings at Railroads

Recommended Practice	Introduction Year	Relationship with Other Recommended Practices or Regulations
American Railway Engineering Association Specifications for Pipelines Conveying Flammable Substances (AREA, 1991)	1932	These recommended practices are used by most railroad companies as specifications and by New York State as regulations.
ANSI/ASME B31.8-1989 (ASME, 1989b)	1935	Portions of ANSI/ASME B31.8 were adopted in the ASCE interim specifications with exceptions. The technical content of the Code of Federal Regulations is almost identical to ANSI/ASME B31.8
ANSI/ASME B31.4-1989 (ASME, 1989a)	1935	Portions of ANSI/ASME B31.4 were adopted with exceptions in the ASCE interim specifications and the API recommended practices for pipeline crossings. The technical content of the Code of Federal Regulations is similar to ANSI/ASME B31.4
API Recommended Practice 1102 (API, 1981) ¹	1952	API Recommended Practice 1102 is adopted in ANSI/ASME B31.4
ASCE Interim Specifications (Committee on Pipeline Crossings of Railroads and Highways, 1964)	1964	Not adopted as part of other recommendations or regulations, but influential in focusing attention on design procedures for external loads
ASME Guide for Gas Transmission and Distribution Piping Systems - 1986 (ASME, 1986)	1970	Provides supplementary design recommendations to the Code of Federal Regulations minimum safety standards

ANSI — American National Standards Institute

API — American Petroleum Institute

AREA — American Railway Engineering Association

ASCE — American Society of Civil Engineers

ASME — American Society of Mechanical Engineers

¹API RP 1102 currently is under revision, with anticipated completion in 1992.

U.S. Performance Record

Important sources of information about pipeline performance are the records compiled by the National Transportation Safety Board (NTSB). Since 1969, the NTSB has been investigating pipeline failures and publishing pipeline accident reports. It should be recognized that NTSB reports do not provide a complete record of safety problems, although they do provide an official account of serious accidents.

Table 2 summarizes four pipeline failures at railway and highway crossings in chronological order. These failures involved case carrier pipes. Included in this table are pipeline characteristics, location and type of crossing, and the probable causes of the failures as determined by the NTSB.

There are several technical issues raised by the incidents. The Monroe, LA failure, for example, illustrates that carrier pipes within casings are subject to flexure, increasing longitudinal stresses in the pipeline.

The Manassas, VA and Beaumont, KY failures indicate difficulties associated with the corrosion control of cased steel carrier pipes. These two pipeline failures illustrate the following potential

problems: 1) damage to protective coatings of carrier pipes during installation into casings, 2) penetration of groundwater into the annular space between carrier pipes and casings, 3) providing for and confirming electrical isolation between carrier pipes and casings, 4) the shielding effect of casings decreasing corrosion control from cathodic protection systems, and 5) lack of atmospheric corrosion control by conventional cathodic protection systems.

Summary

In summary, practices proposed in the U. S. and abroad have shown a steady trend toward broader and more flexible requirements for pipeline protection at transportation crossings.

COMPREHENSIVE STRESS ANALYSES

As illustrated in Figure 1, the stress state experienced by an uncased carrier pipe beneath a railroad is complex. The pipeline is subjected to external loads which cause the pipe to deform both in transverse cross-section (Figure 1b) and longitudinally (Figure 1e). The pipeline is subjected to internal pressure, which causes circumferential tension and a tendency to shorten along the longitudinal axis of the pipe. In addition, the pipeline may be influenced by changes associated with seasonal variations in temperature and possibly by thrust from bends in the vicinity of the crossing.

The external loads imposed on the pipeline come from the weight of the soil and from vehicular loads at track surfaces. Because of irregularities in track surfaces, vehicular loads often are accompanied by impact forces. The external loads, including soil weight, must be conveyed through the soil. Such conveyance involves three-dimensional stress transfer. Pipe reaction to stress in the soil medium depends on the relative stiffness between the pipe and surrounding ground. This relative stiffness affects both the transverse and longitudinal flexural deformation of the pipe.

Some existing design procedures (e.g., ASME, 1986) account for the stresses induced by transverse flexural deformation, but do not consider the longitudinal flexural or axial stresses. In fact, most pipeline design is based on a two-dimensional transverse representation of the pipe. Neglecting the third dimension raises problems with respect to representing the actual three-dimensional stress system beneath railroad crossings. Furthermore, soil-pipeline interaction needs to be simulated properly at the same time the three-dimensional stress is accounted for.

An analytical approach ideally suited for three-dimensional simulation with proper soil-pipeline interactions is the finite element method. This approach was adopted in the research, using the facilities of the Cornell Program for Computer Graphics. Linear elastic properties of the soil and pipeline were used for production runs only after the effects of nonlinearities were explored through the use of nonlinear, elasto-plastic models in special finite element analyses. These analyses indicated that modeling with linear elastic properties was sufficiently accurate for the pipelines, pipeline depths, and soil types encountered at railroad crossings. As explained later in the paper, full-scale field testing was conducted to confirm that the results of the linear elastic simulations were in agreement with actual measured stresses.

The research was able to take advantage of the Cornell facilities, using interactive graphics to generate finite element meshes, super mini-computers for rapid computation, and color graphics post processing for swift and convenient assessment of the results. The analytical programs used in the projects were all developed at Cornell and include capabilities ranging from static linear elastic analysis to full nonlinear analysis with dynamic loading. A detailed description of the finite element modeling is given elsewhere (Blewitt, et al., 1987; Ingraffea, et al., 1991), and the reader is referred to these sources for additional information.

Nearly 200 production finite element analyses were performed to evaluate, on a systematic basis, pipeline stresses in response to variations in external loads, soil properties, pipeline wall thickness, diameter, and depth. The results of these analyses were collapsed into a limited number of well-defined trends as explained by Ingraffea, et al. (1991) and O'Rourke, et al. (1991c), based on dimensional considerations and the concept of characteristic curves to account for the effects of soil-pipeline stiffness.

Where possible, current design approaches were modified and adopted to preserve the convenience and familiarity associated with long term practices. The result is a comprehensive design methodology which accounts for three-dimensional soil-pipeline interaction, three-dimensional pipeline stresses, and the effects of repeated loading and fatigue.

Table 2. Summary of Pipeline Failures at Railway or Highway Crossings

Pipeline Characteristics	Failure Date	Location	Cause ^a	Reference
30 in. (760 mm) diameter natural gas transmission pipeline constructed in 1956	2 March 1974	Highway; Monroe, Louisiana	Failure of sub-standard girth weld due to repeated stresses from carrier pipe flexure inside a casing.	NTSB, 1975
32 in. (810 mm) diameter refined petroleum products transmission pipeline constructed in 1963	6 March 1980	Highway; Manassas, Virginia	Pressure surge caused failure inside the casing at an area of the carrier pipe thinned by corrosion	NTSB, 1981
6 in. (150 mm) diameter polyethylene natural gas distribution pipeline constructed in 1979	22 February 1985	Railway; Sharpsville, Pennsylvania	Failure of a coupling outside the limits of the casing due to thermal contraction of the plastic carrier pipe within the casing	NTSB, 1985b
30 in. (760 mm) diameter natural gas transmission pipeline constructed in 1952	27 April 1985	Highway; Beaumont, Kentucky	Corrosion of the carrier pipe inside the casing	NTSB, 1985a 1987

^aThe cause of the failures was determined by the NTSB

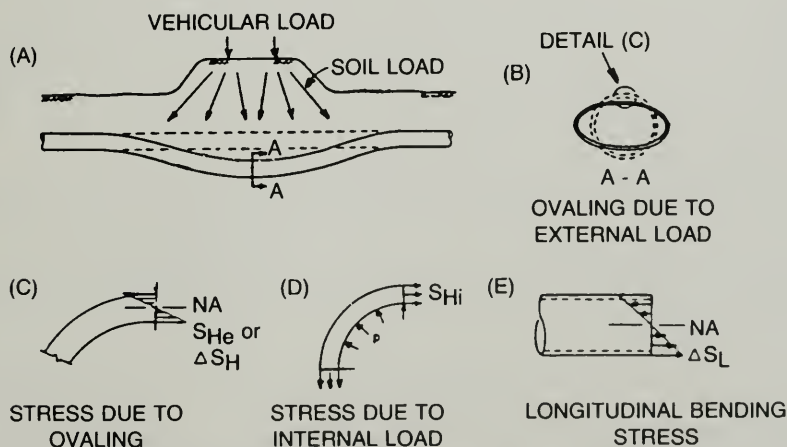


Figure 1. Conditions of Pipeline Deformation and Stress at Crossings

RECOMMENDED DESIGN METHODOLOGY

Uncased pipeline crossings must be designed to withstand external loadings due to earth load and live vehicular load, as well as internal loads generated by pressure. The external loads will generate both circumferential and longitudinal stresses, whereas the internal pressure will contribute primarily to circumferential stresses. To ensure safe operation, all of the stresses must be accounted for in a comprehensive manner. Current design methods can be used to account for circumferential stresses, but do not incorporate longitudinal stresses. The recommended design methodology includes procedures for computing both longitudinal and circumferential stresses generated by external and internal loadings, and using these stresses in checks for both yield and fatigue. Detailed background material related to the development of the design procedure is given by Ingraffea, et al. (1991). The complete design methodology for uncased railroad crossings is given in "Guidelines for Pipelines Crossing Railroads" (Stewart, et al., 1991b), and is published in full in this Bulletin. The reader is referred to that article for the detailed procedures and design curves used to evaluate pipeline stresses.

Stresses Due to Earth Load

The circumferential stresses due to earth load are computed using dimensionless curves developed for auger bored installation methods. These dimensionless curves, described more fully by Ingraffea, et al. (1991), are based on the Marston model (Marston, 1930) for soils consistent with the *in situ* structure and shear strength characteristics of ground above bored and jacked carrier pipes. Soil loads are transferred to the pipe as a function of ground loss during construction, the bored diameter, B_d , the pipe diameter, D , and the depth of cover above the pipe crown, H . The resistance of the pipe to ovaling under these loads is accounted for in terms of soil side reaction and the flexibility of the pipe, characterized by the pipe wall thickness to diameter ratio, t_w/D . A dimensionless stiffness factor accounts for the interaction between the soil and pipe, and depends on both the pipe stiffness, represented in terms of t_w/D , and soil stiffness, characterized by the modulus of soil reaction, E' . Analyses of field data from several test installations, presented by O'Rourke, et al. (1991a), have been used to determine appropriate values of E' for auger bored installations. These data suggest that E' values in the range of 500 to 1000 psi (3.4 to 6.9 MPa) are appropriate for calculating circumferential pipeline stresses due to earth loads at transportation crossings.

Stresses Due to Live Loads

Live surface loadings will cause both circumferential and longitudinal stresses in an uncased carrier pipe. For design purposes, the surface loadings are characterized by a uniform surface pressure, w . Detailed comparisons of the three-dimensional pressure distributions are typical pipeline depths (O'Rourke, et al., 1986 and 1988; Stewart and O'Rourke, 1991a) have shown that uniform surface pressures can be used to represent the loads resulting from train axles and truck wheels. The effects of discrete load points diminishes with depth below the surface, thus making the use of uniform applied surface pressures reasonably accurate and simple to use in a design procedure.

Railroad loadings are determined by using the combined weight of four train axles distributed over an 8-ft. by 20-ft. (2.4-m by 6.1-m) area. The recommended load for railroad crossings is consistent with Cooper E-80 loadings with four 80,000 lb. (356 kN axles). This results in a uniform surface pressure of $2 = 13.9$ psi (96 kPa). The live load applied surface pressure, w , should be increased by an impact factor, F_i , to account for irregularities in the track or roadway surface and dynamic vehicle effects. Special field tests for impact at railroads (Stewart and Behn, 1991a) have indicated that the formulation used in the design procedure is reasonable.

Current methods for evaluating pipeline stresses due to external surface loads do not address the three-dimensional aspects of stress distribution within the foundation soil. In addition, longitudinal bending stresses are ignored completely. For uncased pipelines crossing beneath railroads, the three-dimensional nature of load distribution must be considered when evaluating the overall state of stress within the pipeline.

Parametric studies of pipeline live load response beneath railroads were conducted using fully three-dimensional finite element analyses. The objectives of these analyses, described fully by Blewitt, et al. (1987) for railroads were to determine the input parameters which affect the response of pipelines to live loads, and to quantify the variation in pipeline stresses with respect to all relevant input variables.

Characteristic curves for cyclic circumferential and longitudinal stresses were developed, as a function of soil stiffness, pipe stiffness, and pipeline geometry. Since the purpose of these curves is their direct use as design aids for auger bored crossings, the analyses were performed with 90 degrees of contact between the soil and pipe at the crown and invert, and voids for 90 degrees along the springlines. These conditions represent reasonable upper bounds for load conveyance with minimal side support, as would be typical immediately following installation in an overbored opening. The details of reducing the finite element results to design curves are given by Ingraffea, et al. (1991) and O'Rourke, et al. (1991c).

CURRENT DESIGN PROCEDURES

There are several major differences between the recommended design procedure described above and current design procedures for pressurized pipeline design, such as those proposed by Spangler (1956, 1964). The first is that there are no means for analyzing longitudinal bending stresses when current procedures are used. Circumferential stresses, however, can be computed using currently employed methods. It was Spangler's intention to develop a conservative expression for tensile circumferential stresses at the invert for pressurized pipe. In the conservative approach, no provision was made for soil reaction against lateral deformation of the pipe. In practical terms, it is difficult to see how large vertical loads can be developed on a bored-in-place pipe with absolutely no reaction from soil which deforms or falls into contact with the pipe. The very process of soil deformation onto the top of the pipe must cause some contact along its sides. O'Rourke, et al. (1991a) have presented field data for bored-in-place pipelines and determined that lateral side reactions must be present.

An additional, and significant, feature in the current design procedures based on a Spangler approach is the inclusion of pressure re-rounding, or pressure stiffening. Spangler noted that a pipe deformed by the application of external load would tend to re-round under the application of internal pressure. This re-rounding acts against the load applied to the pipe, resulting in lower pipe curvatures and reduced circumferential stresses. The amount of re-rounding, and consequently the amount of reduction in circumferential stress, would depend on the pipe geometry and internal pressure. Using a pressure stiffening effect in the currently used Spangler approach can result in markedly reduced circumferential stresses, which may not be representative of actual behavior. The following sections present the procedures followed using current practices for calculating pipeline circumferential stresses.

Earth Load

The expression for earth load used in the Spangler procedures is given by

$$W_E = C_d \gamma B_d^2 \quad (1)$$

in which W_E = soil load on the crown per unit length of pipe,

C_d = load coefficient,

= soil unit weight, and

B_d = bored diameter.

The parameter C_d is dependent on the soil type, depth of cover, H , and bored diameter, B_d , as given by

$$C_d = \frac{1 - e^{-2K_\mu (H/B_d)}}{2K_\mu} \quad (2)$$

in which K_μ = coefficient of lateral earth pressures times the coefficient of friction between backfill and *in situ* soil. The equations given above basically are derived from trench construction considerations, but still are applied to auger-bored construction using the Spangler approach.

Live Load

Live loads to pipelines beneath railroads are calculated based on an idealized uniform surface load distributed through a continuous half-space using Newmark's influence coefficients for stresses beneath an 8-ft by 20-ft (2.4-m by 6.1-m) loaded area. The live load acting on the pipe crown is given by

$$W_L = 4 I_z F_i w D \quad (3)$$

in which W_L = live load acting on the crown per unit length of pipe,

I_z = Newmark's influence coefficient,

F_i = impact factor,

w = uniform surface pressure, and

D = pipe diameter.

Circumferential Stresses

The formula used currently for calculating circumferential stress, S_H , at the pipeline invert is given by

$$S_H = \frac{3 K_B W_T E_s D t_w}{E_s t_w^3 + 3 K_Z p D^3} \quad (4)$$

in which K_B = bedding angle constant related to pipe moments,

W_T = total load per unit length, acting on pipe crown = $W_E + W_L$,

E_s = pipe Young's modulus,

D = outside diameter,

t_w = wall thickness,

K_Z = bedding angle constant related to pipe displacements, and

p = internal pressure.

Note that no allowance is made for lateral side support to resist deformations and reduce pipe bending moments. Also, the pipe pressure is included as a term in the denominator of Equation 4, indicating reduced circumferential stresses for increasing internal pressures. In Equation 4, if $W_T = W_E$, then the stress is the earth load circumferential stress, S_{Hc} . If $W_T = W_L$, then the stress is the live load circumferential stress, ΔS_{Hr} .

COMPARISON WITH DESIGN PROCEDURE STRESSES

Since the design procedure based on a Spangler approach does not allow for calculations of longitudinal bending stresses, a direct comparison between stresses computed using the recommended design methodology and current practice is not strictly possible. Since both methods can be used to calculate circumferential stresses, it is useful to compare stresses predicted using both methods, and comment on the differences. To illustrate these differences, an example of an uncased transmission pipeline crossing beneath a railroad is given. The properties used are those for the 36-in. (914-mm) experimental pipeline, described in a later section of this paper. The relevant fixed geometric and material properties are summarized in Table 3. The design checks for the new procedure are given in a later section. The purpose of this portion of the example is to demonstrate the difference in magnitude between computed stresses. Also, temperature effects in this example problem are ignored in computing circumferential stress using the recommended design procedure. Soil properties selected are consistent with those that might be used with a dense sand. Table 4 lists the calculated values for both design methods. In calculating circumferential stresses using the Spangler equations, the earth load and live load stresses will be shown separately so that the results can be compared directly to those computed using the recommended design procedure.

Table 3. Fixed Parameters for Design Procedure Comparisons for 36-in. Pipe

Parameter	Current Practice (Spangler)	Recommended Procedure (Cornell/GRI)
D	36 in. (914 mm)	36 in. (914 mm)
t_w	0.606 in. (15.4 mm)	0.606 in. (15.4 mm)
H	5.8 ft (1.77 m)	6 ft (1.83 m)
B_d	38 in (965 mm)	38 in. (965 mm)
H/B_d	1.83	1.89
γ	0.069 lb/in. ³ (18.9 kN/m ³)	0.069 lb/in. ³ (18.9 kN/m ³)
F_i	1.0	1.0
w	13.9 psi (96 kPa)	13.9 psi (96 kPa)
E_s	30×10^6 psi (206.8 GPa)	30×10^6 psi (206.8 GPa)
ν_s	NA	0.30A
K_μ	0.192	NA
K_B	0.169	NA
K_Z	0.108	NA
Soil type	NA	B
B_d/D	NA	1.06
E	NA	1.8 ksi (12.6 MPa)
E_r	NA	20 ksi (138 MPa)
No. of tracks	NA	1

NA = not applicable

Table 4. Calculated Values for Design Procedure Comparisons for 36-in. Pipe (See Table 3 for Fixed Parameters)

	Current Practice (Spangler)	Recommended Procedure (Cornell/GRI)
$C_d =$	1.31	$t_w/D = 0.017$
$I_z =$	0.165	$K_{He} = 2498$
$W_E =$	131 lb/in. (22.9 kN/m)	$B_e = 0.61$
$W_L =$	330 lb/in. (57.8 kN/m)	$E_e = 0.92$
$W_T =$	461 lb/in. (80.7 kN/m)	$K_{Hr} = 236$
		$G_{Hr} = 0.62$
		$N_H = 1.0$
		$K_{Lr} = 224$
		$G_{Lr} = 0.62$
		$N_H = 1.0$
		$K_{Lr} = 224$
		$G_{Lr} = 0.49$
		$N_L = 1.0$

Figure 2 shows comparisons between circumferential stresses for the 36-in. diameter pipeline, calculated with the current design equations, i.e., Spangler equations, and stresses predicted with the Cornell/GRI recommended procedure. Figure 2 shows the computed earth load stresses, S_{He} . At low internal pressures, the Cornell/GRI procedure predicts significantly smaller earth load stresses than predicted using the Spangler equations. The Spangler equation also indicates that the earth load stresses decrease substantially as internal pressure increases from 0 to 1000 psi (0 to 6.9 MPa). The Spangler equation predicts nearly 70 percent reduction in circumferential earth load stresses in the 36-in. pipe for the pressure range shown. The Cornell/GRI procedure does not include pressure stiffening effects.

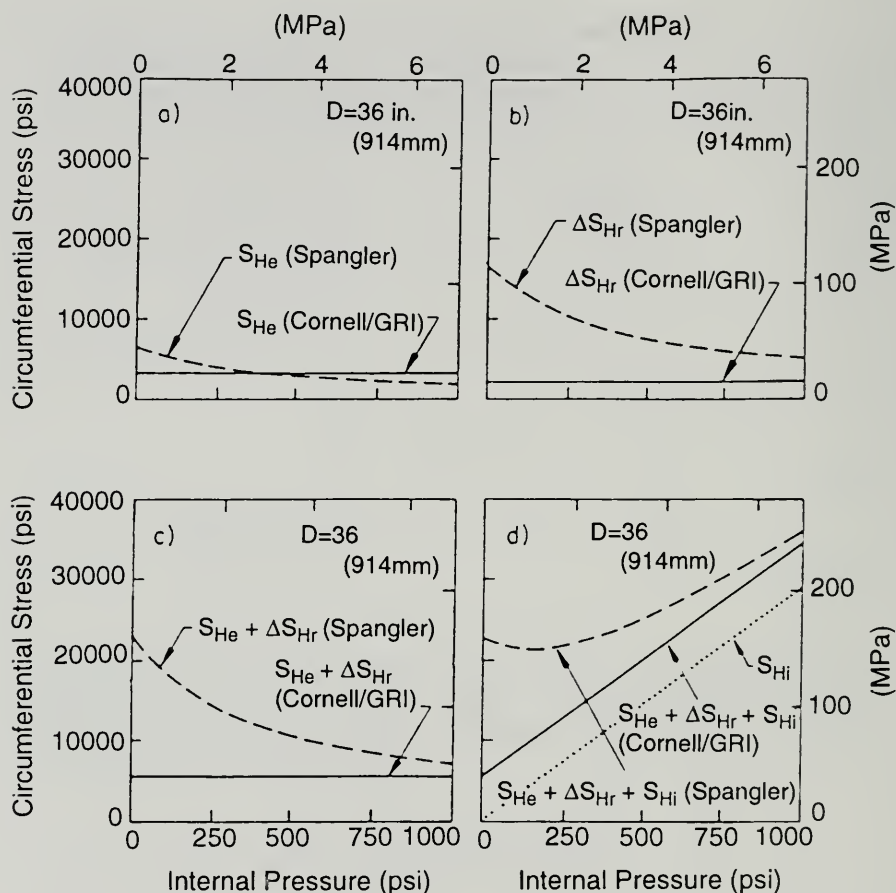


Figure 2. Comparison of Circumferential Stresses in 36-in. Pipe Using Both Design Procedures

Live load stresses, ΔS_{Hr} , are shown in Figure 2. The Spangler equations predict stresses much larger than those calculated using the Cornell/GRI procedure, especially at low internal pressures. At high internal pressures, the reduction in stress that results from the inclusion of a pressure stiffening effect in the Spangler equations is dramatic. As mentioned earlier, the Cornell/GRI procedure does not include stiffening effects. The Spangler method also does not include any means for assessing the load sharing capacity of the soil. The recommended design procedure accounts for the load sharing capacity of the soil by including the soil resilient modulus, E_r , directly in the design curves. Soft soil will result in greater load going onto the pipe than stiff soil. Since uncased pipeline deformations must involve resistance from the surrounding soil mass, softer soil will result in greater transverse pipe deformations and larger circumferential stresses.

Figure 2 shows the combined earth and live load stresses computed using both design procedures. The Spangler equations predict circumferential stresses at zero internal pressure roughly three to four times higher than those predicted using the Cornell/GRI procedure. At an internal pressure of 1000 psi (6.9 MPa), both methods are in reasonable agreement, largely due to compensating errors in the Spangler

equations. The Spangler stresses are reduced due to a large pressure re-rounding term, which is likely to be unconservative.

The combined circumferential stress in an uncased pipeline is the sum of the earth load stress, S_{He} , the live load stress, ΔS_{Hr} , and the stress due to internal pressure, S_{Hi} . Figure 2 shows the combined stresses determined using the Cornell/GRI procedures and the methods used in current practice. For consistency, the internal pressure stress, S_{Hi} , was calculated using the average pipe diameter, $D-t_w$, in both procedures. At low internal pressures, the Spangler equations predict circumferential stresses much greater than those based on the Cornell/GRI methodology. At high internal pressures, the two design methods are in reasonable agreement, only because the Spangler equation reduces the earth and live load stresses due to the inclusion of a questionable pressure stiffening term. Without the pressure stiffening term in the Spangler equation, it would be difficult to satisfy most criteria limiting combined circumferential stress for commonly sized transmission piping operated at typical internal pressures. The Spangler equations rely upon overly conservative estimates of load on the pipeline (Equations 1 and 3), but dramatically overcompensate for this by including a substantial reduction in stress due to pressure stiffening (Equation 4).

Design Checks

The previous section demonstrated that significant differences exist between stresses computed using the currently accepted Spangler design procedure and the recommended Cornell/GRI method. Currently, the only check against limiting stresses is that the circumferential stress generated by internal pressure, S_{Hi} (Barlow), be less than the factored SMYS. The maximum allowable limit on the combined circumferential stress caused by earth load, S_{He} , railroad live load, S_{Hr} , and internal pressure, S_{Hi} , is not explicitly stated in the regulatory statutes, but should be less than SMYS. The Cornell/GRI methodology recommends additional design criteria that take into account the multi-axial state of stress in the pipeline, and considers the effects of the cyclic live load stresses on weld fatigue. To demonstrate these checks, the same transmission lines example will be continued, using the parameters given in Tables 3, 4, and 5. Table 6 lists the calculated stresses and design criteria limiting stresses. For this example, all stresses are below the allowable values. Note that an impact factor of $F_i = 1.0$ was used, and that design should consider such effects. If the stresses exceeded any of the allowable values, the designer would have several options available. These could include thicker pipe wall, greater depth of burial, increased steel grade and perhaps locating the girth weld at a greater distance from the track centerline to take advantage of the three-dimensional load distribution on reducing cyclic longitudinal stresses.

Table 5. Parameters Used in Design Checks for the 36-in. Pipe Example (See Table 4 for Fixed Parameters)

Parameter	Value	Parameter	Value
MAOP	1000 psi (6.9 MPa)	FS	1.4
SMYS	60000 psi (413.7 MPa)	L_G	0 ft (0 m)
Class location	1	R_F	1.0
F	0.6	Longitudinal weld	SAW
E	1.0	SFG	12000 psi (82.7 MPa)
T	1.0	SFL	12000 psi (82.7 MPa)

Table 6. Calculated Stresses and Design Criteria Checks Using the Cornell/GRI Methodology for the 36-in. Pipe Example (See Tables 3, 4, and 5 for Parameters)

a) Calculated Stresses (psi)

S_{He}	S_{Hr}	S_{Hi}	S_{Lr}	S_I	S_2	S_3	S_{eff}
3482	2034	29203	1526	34719	11332	-1000	31424

b) Design Criteria Stresses (psi)

49CFR192		Multi-Axial Yield		Girth Weld Fatigue		Longitudinal Weld Fatigue	
$S_{Hi}(B)$	F-E-T-SMYS	S_{eff}	SMYS/FS	S_{Lr}/N_L	S_{FG}/FS	S_{Hr}/N_H	S_{FL}/FS
29703	36000	31424	42857	1526	8571	2034	8571

1 psi = 6.895 kPa

FULL SCALE FIELD TESTS

Two instrumented high-pressure steel pipelines were installed without casings, using auger boring methods, at the Transportation Test Center (TTC) in Pueblo, CO. Field experiments were conducted to measure pipeline response due to train loading. The effects of vehicle speed, internal pressure, and time since installation were investigated over a two-year period. Loading conditions during the field tests consisted of heavy freight cars having nominal static axle loads of 80000 kips (356 kN), which is consistent with the recommended E-80 loading described previously. The purposes of these field tests were to substantiate the analytical model used to develop the design procedure, and develop a permanent data base of actual pipeline performance at transportation crossings. Figure 3 shows profiles of the two pipelines. The 12.75-in. (324-mm) diameter pipeline has $t_w = 0.25$ in. (6.4 mm) and SMYS = 42000 psi (289.6 MPa). The 36-in. (914-mm)-diameter pipeline has $t_w = 0.61$ in. (15.5 mm) and SMYS = 60000 psi (413.7 MPa). The depth from the top of the railroad cross ties to the crown of each pipe at track centerline is 5.75 ft (1.75 m).

Both pipes were instrumented before field installation. Pipe instrumentation consisted primarily of strain gages on the pipes' exterior and interior at the crown, springlines and invert. Accelerometers, pressure transducers, and temperature sensors also were installed at several pipe locations. The locations of the instrument stations are shown on Figure 3 as solid circles. Strain gage circuits also were installed on the rails above the pipes to measure dynamic rail forces. Details of the pipe fabrication, installation, and data acquisition procedures are given by Ingraffea, et al., (1991), Stewart and O'Rourke (1991b), and Stewart et al., (1991a).

Testing of the pipelines began in July 1988 with measurements made at four- to six-month intervals through Spring 1990. Special impact and impingement testing was conducted to investigate extreme irregularities in the running surface and roadbed, as discussed by Ingraffea et al., (1991) and Stewart and Behn. (1991a). Typical field data will be presented to illustrate the primary findings of the field testing, and to substantiate portions of the design methodology presented earlier.

Pressure Stiffening

The recommended design procedure does not include reductions in the circumferential stress caused by stiffening of the pressurized pipeline. As was shown previously, including a pressure re-rounding effect, such as that used in the current Spangler-type equations, dramatically decreases the predicted circumferential stresses. To investigate the validity of not including a pressure stiffening term, field experiments were conducted at internal pressures ranging from 0 to 1000 psi (0 to 6.9 MPa). During this part of the field testing the impact factor at the test site was very close to $F_i = 1.0$. Figure 4 shows the variations in cyclic circumferential stress, directly below the track centerline, at the inverts of both the

12.75-in. (324-mm) and 36-in. (914-mm)-diameter pipelines. The cyclic circumferential stresses were calculated from strain gages oriented to measure both circumferential and longitudinal strains at the same location. Several important trends are shown in Figure 4. The most significant is that there is only a minor decrease in circumferential stress as pressure increases. This observation also was found consistently for stresses at pipe locations other than the invert. In general, increasing pressures from 0 to 1000 psi (0 to 6.9 MPa) caused decreases in live load circumferential stresses on the order of 10 to 20 percent at most. Using the Spangler equations for the test pipe properties and geometries, stress reductions on the order of 55 to 65 percent would be predicted as pressure increased from 0 to 1000 psi (0 to 6.9 MPa). Based on the field data collected over a two-year period, it is reasonably accurate and conservative to ignore pressure stiffening effects in uncased gas pipelines.

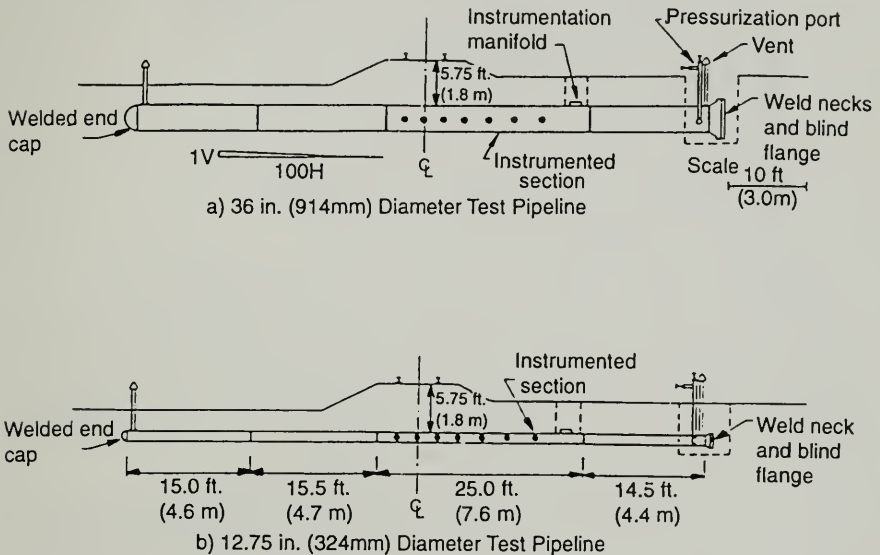


Figure 3. Profile Views of Test Pipelines

Another observation from Figure 4 relates to the magnitude of the measured stresses. Current design methods, such as given by the equations in the earlier section, would predict live load circumferential stresses on the order of 11000 psi (75.8 MPa) at the inside invert of the 12.75-in. (324-mm)-diameter pipe, and approximately 14700 psi (101.4 MPa) at the inside invert of the 36-in. (914-mm) pipe, for zero internal pressure. The field data indicate substantially smaller circumferential stresses than those calculated using the Spangler equations. The tensile stress at the inside invert of the 12.75-in. (324-mm)-diameter was 1880 psi (13.0 MPa), only about 17 percent of that predicted using current design methods. The tensile stress at the invert of the 36-in. (914-mm)-diameter pipe was 1460 psi (10.1 MPa), or roughly 10 percent of that predicted using current design equations. Thus, the field data suggest that pipeline stresses computed using the Spangler approach are overly conservative at low internal pressures and introduce artificial stress reductions at high internal pressures.

The final observation drawn from Figure 4 is that the circumferential stresses are not the same at the pipe interior and exterior walls. Since the three-dimensional load distribution causes longitudinal pipe bending in addition to transverse bending, the entire crown of the pipe experiences compressive longitudinal strains whereas the entire invert experiences tensile longitudinal strains. The inside invert experiences tensile circumferential strains due to the transverse pipe ovaling whereas the circumferential

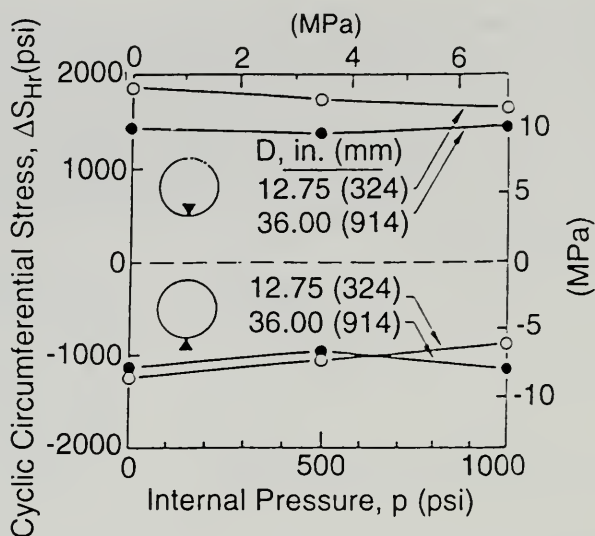


Figure 4. Observed Effects of Internal Pressure on Cyclic Circumferential Stresses

strains on the outside invert are compressive. The combination of tensile longitudinal strains and tensile circumferential strains at the inside invert result in circumferential stresses at the invert that are greater in magnitude and opposite in sign as compared to the outside invert. Thus, the inside invert of the pipe is a reasonable location for calculating design stresses, since the stresses often are the greatest at this location.

Comparison of Field Measurements with Analytical Results

The recommended design curves for live load stresses were based on comprehensive, fully three-dimensional finite element modeling, followed by parametric reduction to simplified design aids. The design curves were constructed as upper bound envelopes to the stresses predicted using the numerical models. As mentioned previously, one of the purposes of the field experiments was to substantiate the analytical modeling techniques for two particular crossing geometries and sets of material properties so that the computer methods could be applied to other crossing geometries having a wide variety of material properties and soil conditions. The following section presents the results of site-specific finite element modeling of the field test installation, and compares the numerical result with field data. Space limitations preclude a full presentation of the comparisons, so only results for the 36-in. (914-mm)-diameter pipeline are shown. Detailed discussions and comparisons are given by Ingraffea, et al. (1991).

Figure 5a shows the distribution of longitudinal strain measured at the crown and invert of the 36-in. (914-mm)-diameter pipeline. Since field data were collected over a two-year period, sufficient data were available to establish 95 percent confidence intervals for the average field measurements. These intervals are shown in Figure 5. The finite element (FEM) results are shown as dashed lines. The boundary conditions for the site-specific FEM analysis were consistent with those upon which the design curves were based, i.e., 90 degree voids centered on the springlines, with contact at the crown and invert. The soil mass resilient modulus, E_r , was taken as 20 ksi (137.9 MPa) for the silty sand at the test site, and the modulus of the voids was taken as 100 psi (0.7 MPa). Both the field measurements and model predictions show compressive strains along the crown of the pipe near the centerline of the track, and tensile strains along the invert, with a transition in the sign of the bending strains occurring roughly 10 ft (3.0 m) from the track centerline. At the pipe invert directly beneath the track centerline, which is the critical design location, the model comparisons are in good agreement with the field measurements. The cyclic

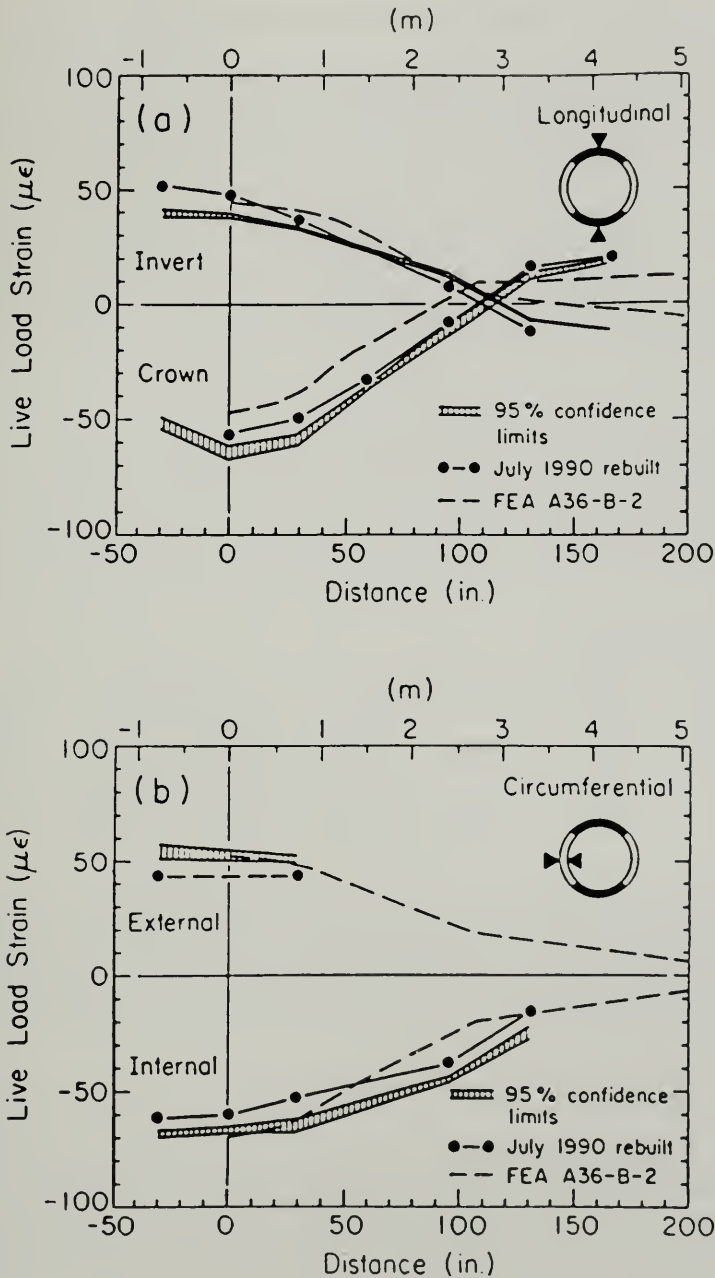


Figure 5. Measured and FEM Live Load Strains in 36-in. (914-mm) Diameter Pipeline

circumferential strains measured at the crown of the pipe near the track centerline are somewhat larger than the FEM results.

Figure 5b shows the measured and predicted live load circumferential strains at one of the pipe springlines. The finite element results compare favorably with the field data, particularly with respect to the distribution of strain with distance from track centerline. The maximum strains occur directly beneath the track centerline, where the field data are consistent with those predicted by the site-specific analysis.

The 12.75-in. (324-mm)-diameter test pipe was also modeled numerically. Results similar to those shown in Figure 5 were obtained for longitudinal and circumferential strain distributions. Ingraffea, et al. (1991) give detailed presentations of the specific results.

Table 7 presents the live load cyclic circumferential and longitudinal stresses, ΔS_{Hr} and ΔS_{Lr} , respectively, at the track centerline position from the field measurements, site-specific finite element analyses, and predicted using the recommended design curves and equations. An impact factor of $F_i = 1.0$ was used in the FEM analyses and design curve calculations, consistent with measured dynamic wheel loads at the time the field testing was conducted.

For the 12.75-in. (324-mm)-diameter pipe, the FEM and design curves over-predict the cyclic circumferential stresses. This is due to pipe support conditions at the springlines for the analytical predictions being better than those actually developed in the field for this pipe. The design curve ΔS_{Hr} is substantially greater than that measured in the 12.75-in. (324-mm)-diameter pipe because very soft springline voids are assumed in the design curves. The predicted longitudinal cyclic stresses, ΔS_{Lr} , in the 12.75-in. (324-mm)-diameter pipe are in excellent agreement with both analytical predictions.

Table 7. Comparison of Predicted Live Load Cyclic Stresses at Track Centerline for Field Installation

Pipe Diameter D (in.)	Circumferential, S_{Hr} (psi)			Longitudinal, S_{Lr} (psi)		
	Measured	FEM	Design Curves	Measured	FEM	Design Curves
12.75	1880	2360	3240	2800	2460	2920
36	2410	2050	2030	1460	1480	1530

1 psi = 6.895 kPa; 1 in. = 25.4 mm

The analytical predictions using FEM results and design curves are in excellent agreement for both the circumferential and longitudinal cyclic stresses in the 36-in. (914-mm)-diameter pipe. The measured circumferential stresses are only about 400 psi (2.8 MPa) higher than those predicted using the simplified design curves. The longitudinal stresses are 70 psi (0.5 MPa) less than those predicted using the recommended design curves.

DESIGN GUIDELINES

The design procedure developed at Cornell through sponsorship from GRI has resulted in sets of concise design guidelines (Stewart, et al., 1991b) that outline the steps required to use the methodology. These Guidelines include all equations and curves necessary to design uncased gas pipelines crossing beneath railroads, focusing specifically on the design of the carrier pipe to accommodate safely the stresses and deformations at transportation crossings. These Guidelines, supplemented by the Technical Summary and Database (Ingraffea, et al., 1991) provide the most recent technology to calculate stresses in uncased pipelines. These Guidelines include several detailed example problems to familiarize the designer with the methodology, and provide tables of typical values for various material properties. In addition, the Guidelines include a brief discussion of typical installation procedures and special considerations such as optimal locations of longitudinal and girth welds in uncased crossings.

AREA MANUAL OF RECOMMENDED PRACTICE REVISIONS FOR UNCASED CROSSINGS

In 1988, the Pipelines Subcommittee of AREA Committee 1 - Roadway and Ballast, began discussions related to developing new Manual material for an uncased crossing option. This was necessitated because of the increasing number of uncased crossing applications being received, and the need to develop a recommendation that could be used to assist railroad engineering staff in making decisions, and provide guidance to railroads not having a full engineering department. As the GRI-funded research was being done, the AREA participated in research advisory meetings, planning field experiments, and reviewing all stages of the project. This interaction provided a basis for understanding the technical and institutional issues involved in pipeline stress analysis, and provided a balanced research approach. In 1991, the Subcommittee was officially charged with the assignment of developing specifications for uncased gas pipelines within the railway right-of-way (Assignment D5-3-91).

The minimum (nominal) wall thicknesses given in the Manual of Recommended Practice were developed using the Cornell/GRI Guidelines. The calculations were performed using the computer program PC-PISCES that implements the full Cornell/GRI design methodology for IBM-compatible personal computers (Stewart and Behn, 1991b). The Cornell/GRI methodology is a design procedure that involves selection of material properties, crossing geometry, loading conditions, and allowable stresses. Although the design procedure itself is straightforward, like all engineering designs there are no unique solutions. It is a process that requires evaluations and decisions that reflect good and prudent engineering. Thus, each crossing design is unique. However, to provide guidance, a set of conservative design parameters were evaluated and selected for use in developing usable tables of wall thickness for typical pipe diameters and steel grades, for a range of internal pressures.

Table 8 lists the fixed parameters used in the analyses. Fixed properties for the steel were $E_s = 30 \times 10^6$ psi (206.8 GPa), $\nu_s = 0.30$ and $\alpha_T = 6.5 \times 10^{-6}$ per $^{\circ}\text{F}$ (1.7×10^{-5} per $^{\circ}\text{C}$). Temperature changes were not considered. Two design parameters that have a major influence on the minimum required wall thicknesses are the internal pressure (MAOP) and minimum specified yield strength (SMYS) of the steel. Wall thicknesses were developed for MAOP = 0 to 2000 psi (0 to 13.8 MPa) in 100 psi (690 kPa) step increments. SMYS values were 35000 psi (241 MPa), 42000 psi (290 MPa), 52000 psi (359 MPa), 60000 psi (414 MPa), and 70000 psi (483 MPa). Fatigue endurance limits were determined using the values given in the Cornell/GRI Guidelines for the various steel grades.

The depth of the uncased carrier pipe was considered two ways. The minimum depth recommended in the Manual for uncased pipelines is 10 ft (3.0 m) below the track structure and 6 ft (1.8 m) below grade or ditches at all other locations within the right-of-way. For relatively large diameter pipelines at depths greater than 10 ft (3.0 m), the increase in earth load may be greater than the decrease in live load, resulting in thicker wall requirements as depth increases. To accommodate these competing live load and dead load effects, the minimum wall thickness was taken as the largest of all minimum calculated values over the depth range of 10 to 14 ft (3.0 m to 4.3 m). For pipelines installed at depths greater than 14 ft (4.3 m), live load stresses are reduced greatly, earth load stresses increase only for diameters greater than about 20 in (508 mm), and the net effect on combined stresses is such that no increases in wall thickness are required to maintain stresses well within limiting ranges.

It should be recognized that not all crossing situations will have the same conditions as those for which the Manual's table of values were prepared. The Cornell/GRI Guidelines were intentionally formulated so that pipelines could be designed in the same manner that all civil engineering structures are designed, rather than prescribed. Differences between actual site conditions and those given in Table 8 may necessitate the use of site-specific calculations for uncased pipelines. The recommended design methodology is flexible and can readily accommodate a wide range of material properties, crossing geometries, loadings, and rational selection of allowable stress limits. The wall thicknesses given in the

AREA Manual of Recommended Practice for uncased pipelines reflect a conservative set of design assumptions that should be satisfactory for a wide range of crossing situations.

Table 8. Fixed Design Parameters for Uncased Wall Thicknesses in AREA Manual

Parameter	Value
a) Earth Load	
B_d	$D + 2 \text{ in. } (D + 51 \text{ mm})$
γ	$0.069 \text{ lb/in.}^3 [120 \text{ lb/ft}^3 (18.9 \text{ kN/m}^3)]$
Soil Type	A (Loose to medium dense sands and gravels; soft clays and silts)
E'	$0.5 \text{ ksi } (1.4 \text{ MPa})$ (Soft to medium clays with low to medium plasticities; loose sands and gravels)
b) Live Load	
w	$13.9 \text{ psi } (96 \text{ kPa})$ (E-80 loading)
E_T	$10 \text{ ksi } (69 \text{ MPa})$ (Stiff to very stiff clays and silts; loose to medium dense sands and gravels)
No. of tracks	2
c) Allowable Stresses	
F	0.6
E	1.0
T	1.0
L_G	0 ft (girth weld at track centerline)
Longitudinal Weld	SAW (submerged arc weld)
FS	1.5

CONCLUSIONS

Rigorous analytical and field experimental research has been directed towards the development of design guidelines for uncased piping beneath railroads. State-of-the-art reviews of practices at railroad crossings has led to an unbiased comparison of the technical issues related to cased and uncased crossings. An understanding of the technical issues and stress environment in uncased carrier piping has led to the development of analytical modeling techniques which have been used to produce effective, yet simple to use, design guidelines. These design guidelines have been developed based on extensive interaction with advisors from both the railroad and gas industries throughout the research program, including critical review of all technical approaches and decisions.

The research has demonstrated that pipelines can withstand railroad loading without the need of casings. Specific design procedures have been developed to calculate the wall thickness or depth of burial required to reduce stresses to within allowable limits. These design procedures were developed using three-dimensional computer analyses, which have given the first comprehensive view of pipeline stresses in uncased crossings, and provide the basis for providing industry with a means for alternative pipeline design and construction practice.

Several main points have been identified through the analytical and field experiments. The experiments have shown the importance of including longitudinal stresses when evaluating uncased pipeline stresses. Current design methods ignore this important stress component. The experiments also have shown that current design methods are inaccurate with respect to the magnitude of predicted circumferential stresses. Circumferential stresses measured in two typically-sized transmission pipelines were much smaller than those predicted using the Spangler approach. Moreover, these circumferential stresses did not decrease substantially as internal pressure increased from 0 to 1000 psi (0 to 6.9 MPa). Current design methods predict dramatic circumferential pressure stiffening effects, which were not measured in full-scale field experiments.

Comparison between full-scale field measurements, site-specific finite element analyses, and simplified analyses using the recommended design curves were given. The design curves were shown to be accurate, yet reasonably conservative. The design curves predict upper bound stress levels, as intended, because of the support conditions assumed. Support conditions along the carrier pipe springlines which are better than the conservative boundary conditions assumed, will result in pipeline stresses that are lower than those computed using the simplified methodology.

The design conditions used to develop the tabulated minimum wall thicknesses for uncased crossings as given in the AREA Manual of Recommended Practice were explained. These design conditions represent conservative assumptions related to pipeline crossing geometry and allowable stresses. Situations certainly will arise when specific analyses need to be performed because the site conditions are different from those for which the tables were generated. The recommended Cornell/GRI design methodology provides the necessary design equations and curves to perform site-specific analyses.

ACKNOWLEDGMENTS

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REFERENCES

- American Petroleum Institute, "Recommended Practice for Liquid Petroleum Pipelines Crossing Railroads and Highways," *API Recommended Practice 1102*, 5th Ed., Washington, DC, Nov. 1981, 19 p.
- American Railway Engineering Association, *Manual for Railway Engineering*, Chapter I, "Roadway and Ballast," AREA, Washington, DC, 1991, pp. I-5-1.
- American Society of Mechanical Engineers, "ASME Guide for Gas Transmission and Distribution Piping Systems-1986," 6th Ed., ASME, New York, NY, May 1986, 325 p.
- American Society of Mechanical Engineers, "Liquid Transportation Systems for Hydrocarbons, Liquid Petroleum Gas, Anhydrous Ammonia, and Alcohols," *ANSI/ASME B31.4-1989*, ASME, New York, NY, July 1989a.
- American Society of Mechanical Engineers, "Gas Transmission and Distribution Piping Systems," *ANSI/ASME B31.8-1989*, ASME, New York, NY, Feb. 1989b.
- Blewitt, J.R., A.R. Ingraffea, T.D. O'Rourke, and H.E. Stewart, "Analytical Study of Stresses in Transmission and Distribution Pipelines Beneath Railroads," *Report No. GRI-87/0234*, Gas Research Institute, Chicago, IL, Sept. 1987, 156 p.
- Committee on Pipeline Crossings of Railroads and Highways, "Interim Specifications for the Design of Pipeline Crossings of Railroads and Highways," ASCE, New York, NY, Jan. 1964.
- Ingraffea, A.R., T.D. O'Rourke, H.E. Stewart, M.T. Behn, A. Barry, C.W. Crossley, and S.L. El-Gharbawy, "Technical Summary and Data-base for Guidelines for Pipelines Crossing Railroads and Railroads," *Report No. GRI-91/0285*, Gas Research Institute, Chicago, IL, Dec., 1991.
- Institution of Gas Engineers, "Recommendations on Transmission and Distribution Practice," *IGETD/1: Complete Edition 2:1984*, IGE, London, U.K., 1984.
- Marston, A., "The Theory of External Loads on Closed Conduits in the Light of Latest Experiments," *Bulletin 96*, Engineering Experiment Station, Iowa State College, Ames, IA, Feb. 1930.

- National Transportation Safety Board, "Michigan-Wisconsin Pipeline Company Gas Transmission Line Failure, South of Monroe, Louisiana, Mar. 2, 1974," *Pipeline Accident Report No. NTSB-PAR-75-1*, Washington, DC, Apr. 1975.
- National Transportation Safety Board, "Colonial Pipeline Company Petroleum Products Pipeline Failures, Manassas and Locus Grove, Virginia, March 6, 1980," *Pipeline Accident Report No. NTSB-PAR-81-2*, Washington, DC, Jul. 1981.
- National Transportation Safety Board, "Texas Eastern Gas Pipeline Company Pipeline Rupture and Fire Near Beaumont, Kentucky, April 27, 1985," transcript of public hearing before the National Transportation Safety Board, Bureau of Accident Investigation, Houston, TX, Oct. 1985a.
- National Transportation Safety Board, "National Fuel Gas Company, Natural Gas Explosion and Fire, Sharpsville, Pennsylvania, February 23, 1985," *Pipeline Accident Report No. NTSB-PAR-85-02*, Washington, DC, Oct. 1985b.
- National Transportation Safety Board, "Texas Eastern Gas Pipeline Company Ruptures and Fires at Beaumont, Kentucky on April 27, 1985 and Lancaster, Kentucky on February 21, 1986," *Pipeline Accident Report No. NTSB-PAR-87-01*, Washington, DC, Feb. 1987.
- Office of the Federal Register, "Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards," *Code of Federal Regulations*, Title 49, Part 192, General Services Administration, National Archives and Records Service, Washington, DC, Nov. 1990a, pp. 578-633.
- Office of the Federal Register, "Transportation of Hazardous Liquids by Pipeline: Minimum Federal Safety Standards," *Code of Federal Regulations*, Title 49, Part 195, General Services Administration, National Archives and Records Service, Washington, DC, Nov. 1990b, pp. 675-701.
- O'Rourke, T.D., A.R. Ingraffea, H.E. Stewart, G.L. Panozzo, J.R. Blewitt, and M.S. Tawfik, State-of-the-Art Review: Practices for Pipeline Crossings at Railroads," *Report No. GRI-86/0210*, Gas Research Institute, Chicago, IL, Aug. 1986, 224 p.
- O'Rourke, T.D., A.R. Ingraffea, H.E. Stewart, C.W. Crossley, G.L. Panozzo, J.R. Blewitt, M.S. Tawfik, and A. Barry, "State-of-the-Art Review: Practices for Pipeline Crossings at Highways," *Report No. GRI-88/0287*, Gas Research Institute, Chicago, IL, Sept. 1988, 208 p.
- O'Rourke, T.D., S.L. El-Gharbawy, and H.E. Stewart, "Soil Loads at Pipeline Crossings," *Proceedings, ASCE Specialty Conference on Pipeline Crossings*, Denver, CO, March 1991b, pp. 235-247.
- O'Rourke, T.D., K.B. Burnham, B.M. New, H.E. Stewart, and A.R. Ingraffea, "Practice and Performance Record for Pipelines at Railroad and Highway Crossings," *Proceedings, ASCE Specialty Conference on Pipeline Crossings*, Denver, CO, March 1991b, pp. 248-261.
- O'Rourke, T.D., H.E. Stewart, A.R. Ingraffea, and S.L. El-Gharbawy, "Influence of Soil-Pipeline Stiffness on Bending Stresses from Surface Loading," *Proceedings, ASCE Specialty Conference on Pipeline Crossings*, Denver, CO, March 1991c, pp. 406-417.
- Spangler, M.G., "Stresses in Pressure Pipelines and Protective Casing Pipes," *Journal of the Structural Engineering Division*, ASCE, Vol. 82, No. ST5, Sept. 1956, 33 p.
- Spangler, M.G., "Pipeline Crossings Under Railroads and Highways," *Journal of the American Water Works Association*, Aug. 1964, pp. 1029-1046.
- Stewart, H.E. and M.T. Behn, "Impact Effects on Pipelines Beneath Railroads," *Research Record 1315*, Transportation Research Board, Washington, DC, pp. 1-6.

- Stewart, H.E. and M.T. Behn, "User's Guide for PC-PISCES Version 1.0 (*Personal Computer - Pipeline Soil Crossing Evaluation System*)," *Report No. GRI-92/0202*, Gas Research Institute, Chicago, IL, Dec. 199b, 84 p.
- Stewart, H.E., M.T. Behn, and T.D. O'Rourke, "Instrumentation of High Pressure Pipelines Installed Using Auger Boring Methods," *Proceedings*, ASCE Specialty Conference on Pipeline Crossings, Denver, CO, March 1991a, pp. 262-279.
- Stewart, H.E. and T.D. O'Rourke, "Live Loads for Pipeline Design at Railroads and Highways," *Proceedings*, ASCE Specialty Conference on Pipeline Crossings, Denver, CO, March 1991a, pp. 317-329.
- Stewart, H.E. and T.D. O'Rourke, "High Speed Data Systems for Field Testing," *Proceedings*, ASCE Geotechnical Engineering Congress, Boulder, CO, June 1991b.
- Stewart, H.E., T.D. O'Rourke, A.R. Ingraffea, A. Barry, M.T. Behn, C.W. Crossley, and S.L. El-Gharbawy, "Guidelines for Pipelines Crossing Railroads," *Report GRI-91/0283*, Gas Research Institute, Chicago, IL, Dec. 1991b.

TIE PERFORMANCE AT DES PLAINES — RECENT DEVELOPMENTS (AAR Research Report)

By: D. D. Davis, K. J. Laine**, and P. Chow*****

1.0 INTRODUCTION

The Association of American Railroads (AAR), in conjunction with the Railway Tie Association (RTA) and the Chicago and North Western Transportation Company (CNW) has performed a series of tie tests at the Des Plaines, Illinois test site to determine the effect of tie length, cross-section, and spacing on tie performance. This report is the ninth in a series of progress reports based on these tests. Objective measurements of track and individual tie performance were made during 1990. Subsequent to inspection a second tie renewal was also performed in 1990. These performance data were used to determine historical and recent tie deterioration rates.

Laboratory tests of some of the ties removed in 1988 and 1990 by the railroad provide further data on tie deterioration. Tie mechanical strength and creosote retention were compared to field performance.

1.1 Background

The Des Plaines test consists of eight sections of treated wooden crossties of various sizes and spacings. The purpose of the test is to evaluate the performance of the test configurations subjected to actual traffic. The effects of tie cross-section, length and spacing on tie performance will be examined. Exhibit 1 lists the test section configurations. More detailed information on the test site may be found in past progress reports.[1-8]*

Test Section	Number of Test Ties	Tie Configuration (in x in x ft)	Tie Spacing (inches)
One	480	6 x 8 x 9	19.5
Two	477	7 x 9 x 10	19.5
Three	431	7 x 9 x 9	19.5
Four	479	7 x 9 x 8.5	19.5
Five	400	7 x 9 x 8.5	23.4
Six	291	7 x 9 x 8.5	27.5
Seven	321	7 x 12 x 8.5	29.3
Eight	399	7 x 12 x 8.5	23.4

Exhibit 1. Test Section Configuration

*Numbers enclosed in brackets refer to the References listed in Section 5.0

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2.0 PERFORMANCE MEASUREMENTS

2.1 Tie Moisture Content

Moisture content measurements were made on a 10% sample of ties in each section. A resistance type moisture meter was used for measurements and readings were taken with a one-inch probe at a point one foot from the gage side of the South rail. Exhibit 2 gives the average values and standard deviations for each test section.

The average moisture content value across sections is relatively stable. The highest average values occur in Sections 5, 6 and 7. Section 5 is on a fill, which tapers to grade in Section 6. Section 7 is at or slightly below grade due to an overpass at the far end. The variability of the moisture contents is substantial, with standard deviations of 1/3 to 1/2 of the mean values. Some of the variability is due to the variability of the wood material, and some of it is due to the condition of the ties. The age of the ties was also found to be a significant factor. Exhibit 3 shows tie moisture content distributions for the original (23 year old) ties and the replacement (2 year old) ties. Exhibit 4 lists these values. The difference between the two groups may be summarized as follows:

The replacement ties have an average moisture content of 36% and a standard deviation of 13.4%. The original ties have an average moisture content of 32% and a standard deviation of 11.9%. The replacement ties have a higher average value, and more scatter in the data. The distribution is more symmetrical in the replacement ties than the original ties, which have a few extreme (high) values.

The replacement ties have a higher average value and higher standard deviation because of the creosote treatment process. These ties were dried to below maximum moisture level before treatment. Since the ties do not dry at the same rate, there is considerable variability in the moisture content. Also, the replacements have a much more uniform condition than the original ties (after 23 years of service). The original ties show the effects of the environment in their moisture content distribution. The ties usually lose moisture after placement in track. In good support conditions (i.e. clean to partially fouled ballast), the ties will dry from treatment moisture contents of 40-50% to field moisture contents of 20-30%.

The original tie moisture content distribution has a "tail" of high moisture content ties. These extreme value ties are in a deteriorated condition, ranging from incipient decay (i.e. structural splits and checks) to actively growing decay.

Test Section	Tie Cross Section (inch x inch)	Tie Length (feet)	Tie Spacing (inches)	Number of Samples	Moisture Content (Percent)	
					Average	Std. Dev.
One	6 x 8	9	19.5	48	29.58	8.18
Two	7 x 9	10	19.5	48	30.90	11.87
Three	7 x 9	9	19.5	48	30.10	9.41
Four	7 x 9	8.5	19.5	49	33.27	14.03
Five	7 x 9	8.5	23.4	40	36.28	12.02
Six	7 x 9	8.5	27.5	44	36.27	14.33
Seven	7 x 12	8.5	29.3	32	33.69	9.25
Eight	7 x 12	8.5	23.4	41	34.15	16.25
ALL				350	32.87	12.47

Exhibit 2. Tie Moisture Content Values.

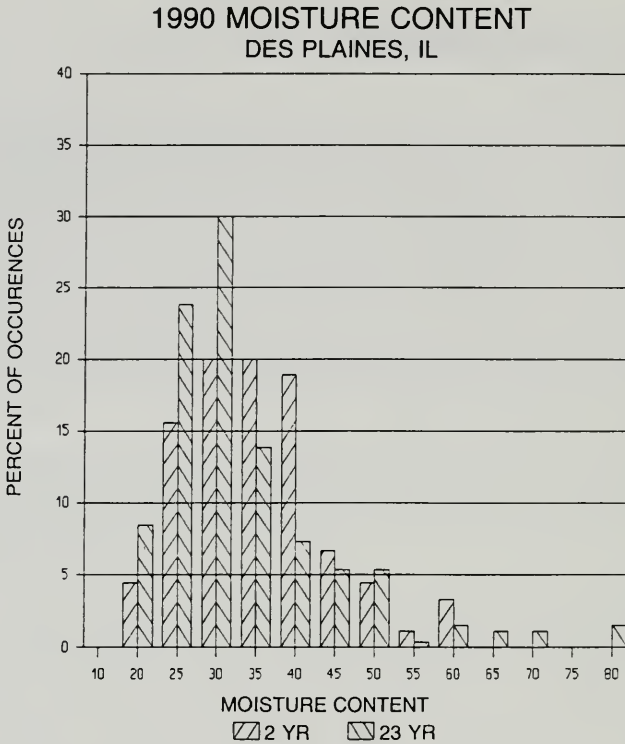


Exhibit 3. Tie Moisture Content Distributions.

Test Section	Ties Installed in 1988			Ties Installed in 1967		
	No. of Samples	Moisture Content (Percent)		No. of Samples	Moisture Content (Percent)	
		Average	Std. Dev.		Average	Std. Dev.
One	11	35.09	6.69	37	27.95	7.86
Two	5	27.20	7.44	43	31.33	12.21
Three	13	26.69	4.91	35	31.37	10.32
Four	13	38.92	16.33	36	31.22	12.48
Five	20	38.60	11.43	20	33.95	12.14
Six	11	42.09	13.10	33	34.33	14.19
Seven	11	33.18	6.53	21	33.95	10.38
Eight	6	43.83	25.74	35	32.49	13.30
ALL	90	35.98	13.39	260	31.79	11.94

Exhibit 4. Tie Moisture Content by Test Section and Tie Age.

Test Section	Ties Installed in 1988 Plate Cutting (inches)							
	No. of Samples	LF* Avg.	LG* Avg.	RG* Avg.	RF* Avg.	Left Avg.	Right Avg.	All Avg.
One	11	0.14	0.02	0.22	-0.02	0.08	0.10	0.09
Two	5	0.12	0.03	0.17	-0.02	0.08	0.08	0.08
Three	13	0.13	-0.01	0.17	-0.04	0.06	0.06	0.06
Four	13	0.13	0.02	0.19	-0.01	0.07	0.09	0.08
Five	20	0.15	-0.03	0.19	-0.06	0.06	0.07	0.06
Six	9	0.16	-0.01	0.16	-0.07	0.08	0.05	0.06
Seven	11	0.24	0.06	0.32	-0.06	0.15	0.13	0.14
Eight	6	0.13	0.01	0.16	-0.03	0.07	0.07	0.07
ALL	88	0.15	0.01	0.20	-0.04	0.08	0.08	0.08

Test Section	Ties Installed in 1967 Plate Cutting (inches)							
	No. of Samples	LF* Avg.	LG* Avg.	RG* Avg.	RF* Avg.	Left Avg.	Right Avg.	All Avg.
One	37	0.65	0.53	0.74	0.54	0.59	0.64	0.62
Two	43	0.58	0.43	0.58	0.45	0.51	0.51	0.51
Three	35	0.56	0.44	0.55	0.32	0.50	0.43	0.47
Four	36	0.46	0.36	0.54	0.30	0.41	0.42	0.41
Five	20	0.47	0.36	0.54	0.25	0.42	0.40	0.41
Six	21	0.47	0.39	0.53	0.28	0.43	0.40	0.41
Seven	22	0.80	0.95	1.11	0.63	0.88	0.87	0.87
Eight	35	0.57	0.44	0.56	0.43	0.50	0.49	0.50
ALL	249	0.57	0.48	0.63	0.40	0.52	0.52	0.52

* LF = Left Field, LG = Left Gage, RG = Right Gage, RF = Right Field

Exhibit 5. Tie Plate Cutting by Test Section and Tie Age.

2.2 Tie Plate Cutting

Plate cutting measurements were made on a 10% sample of ties in each section with the AAR plate cutting measurement device.^[9] The same tie numbers were measured in 1988 prior to the first tie renewal. Thus, the original ties from this group have been measured more than once; allowing recent plate cutting rates to be determined.

Exhibit 5 shows the average values measured for each tie plate location in each section. Section 7 ties have performed the worst. These ties are noticeably plate cut; with average values that approach/exceed the plate thickness.

Exhibit 6 is a plot of tie plate cutting vs tie number. The data has been divided into two groups: the original ties (23 years) and the renewal ties (2 years). The plot shows the variability of tie performance as well as the differences in performance between the sections.

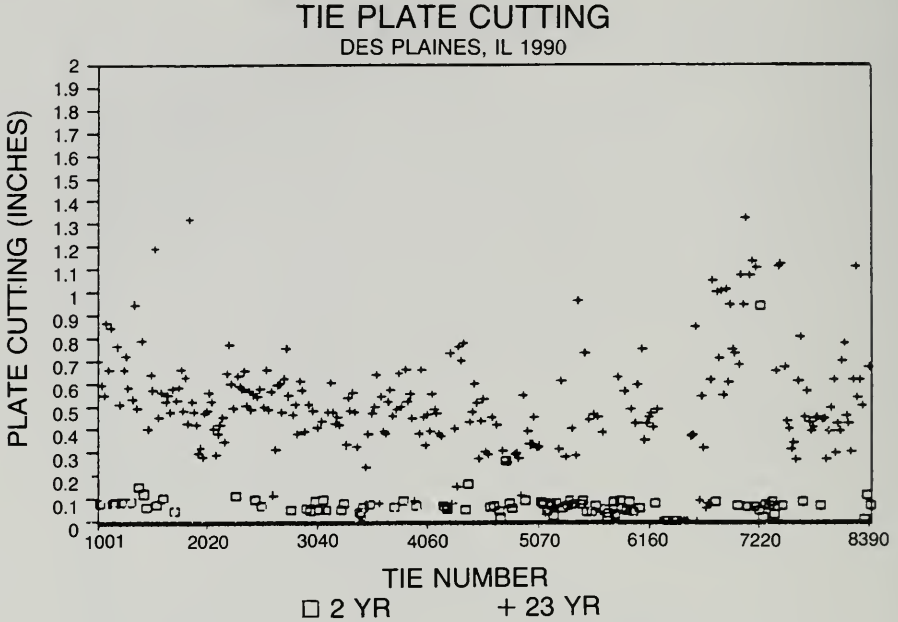


Exhibit 6. Tie Plate Cutting

Exhibit 7 shows histograms of plate cutting for each age group. The distribution for the original ties is symmetrical about the average of 0.52 inches. The range of values is from near zero to 1.4 inches.

The replacement ties show a much more uniform distribution. After two years in track, the average plate cutting value was 0.09 inches. About 90% of the values were between zero and 0.10 inches.

There was an extreme value in the new tie data. One replacement tie had a plate cutting value of 0.94 inches. This tie was located in Section 7 at a low spot near a drainage structure. In addition, the ties were near two battered welds. These conditions combined to cause a pumping, muddy vertical discontinuity in the track surface. The additional loading and rail/tie motion have caused rapid deterioration of the tie plate area of a group of 5 or 6 ties. In two years (or less time) the tie has plate cut almost an inch. The dried mud in the area contains wood fibers; indicating that deterioration of the tie bottom is also occurring. This small section of rapidly deteriorating ties shows the importance of good maintenance to track component life. Under heavy traffic, surface defects lead to rapid deterioration of track structure.

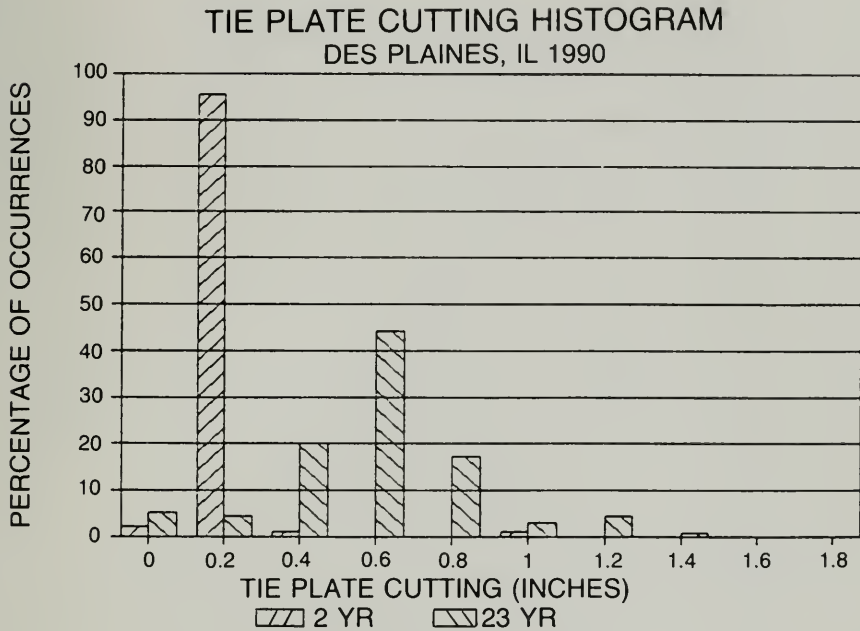


Exhibit 7. Tie Plate Cutting Histogram

2.3 Unloaded Gage

The measurement was made with a gage bar on unloaded track and was taken at every 10th tie in each test section. Unloaded gage provides a mere indication of loaded gage; and can under-represent weak spots. The results of the gage measurement are shown in Exhibit 8. The average gage and standard deviation are given for each test section and the same quantities are given for the gage error (i.e. gage measurement minus nominal gage). These values are all within government safety limits. The average gage error measurements of 1/8 to 1/4 inch are typical of mainline tangent track. All sections were performing well and no significant effects from tie spacing, cross-section or length were noticed.

A comparison of the original ties and the 1988 replacement ties was made on a site-wide basis. Exhibit 9 shows the gage distributions of each group which are quite similar in central tendency and scatter. This result is quite expected since little, if any, regaging was done during the tie renewal.

2.4 Loose Spike Survey

In conjunction with other measurements, the data recorder conducted a line spike kick test. This test consisted of lightly kicking each line spike to check for looseness. The spikes were coded by location as follows: 1 = left field side, 2 = left gage side, 3 = right gage side, 4 = right field side.

A ten percent sample was inspected. The results, listed in Exhibit 10, show the distribution of loose spikes in the ties. There were no loose spikes in the ties installed in 1988. Of the ties installed in 1967, about 42% had at least one loose spike.

Test Section	Cross Section (in x in)	Length (ft)	Spacing (inches)	Ties Installed in 1967				Ties Installed in 1988			
				Gage (56 + /16) inches				Gage (56 + /16) inches			
				No. of Samples	Avg.	Std. Dev.	Gage Error	No. of Samples	Avg.	Std. Dev.	Gage Error
One	6 x 8	9	19.5	37	7.6	2.07	2.62	11	7.1	2.11	2.11
Two	7 x 9	10	19.5	43	8.3	1.65	3.30	5	9.0	1.41	1.41
Three	7 x 9	9	19.5	35	9.1	1.43	4.06	13	10.2	2.18	2.18
Four	7 x 9	8.5	19.5	35	9.0	1.58	3.97	13	9.5	1.65	1.65
Five	7 x 9	8.5	23.4	20	9.1	1.28	4.05	20	9.2	1.08	1.08
Six	7 x 9	8.5	27.5	32	9.0	1.94	4.00	11	8.9	1.38	1.38
Seven	7 x 12	8.5	29.3	21	7.9	2.10	2.86	11	6.8	1.64	1.64
Eight	7 x 12	8.5	23.4	35	8.4	1.32	3.43	6	8.2	0.90	0.90
ALL				258	8.52	1.77	3.53	90	8.71	1.96	1.96

Exhibit 8. Unloaded Track Gage.

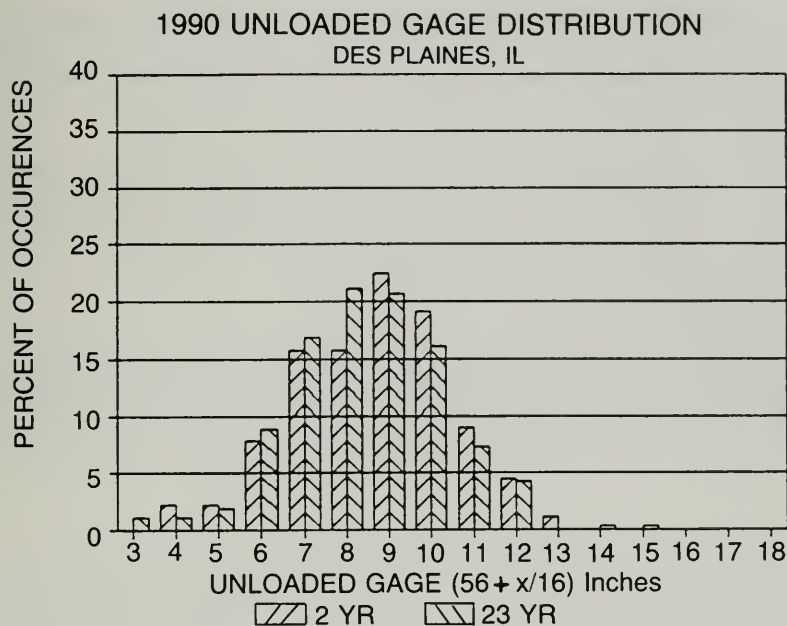


Exhibit 9. Unloaded Gage Distribution.

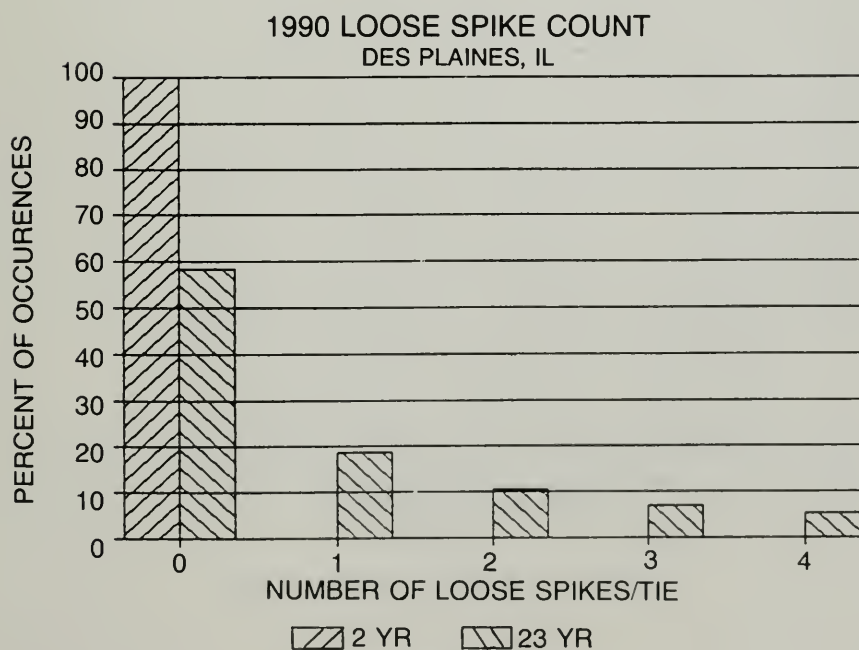


Exhibit 10. Loose Spike Survey.

The distribution of loose spikes by location is given in Exhibit 11. The distribution is relatively even across the tie, with slightly more loose spikes on the gage sides. Since gage widening is not a significant problem on this (tangent) track, lateral forces on the spikes are relatively low and, probably, evenly distributed. Spike loosening is due to the uplift force of the rail and the effects of iron degradation. A section by section count of loose spikes is shown in Exhibit 12.

The absence of loose spikes in the replacement ties after two years in track suggests a significant fatigue or time related component in this process. While spikes may be lifted by the action of the rail, they did not loosen in two years (approx. 80 MGT). In the original ties, after 23 years in track, 42% of the ties have at least one loose spike. It will be interesting to "fill-in" this spike loosening vs. age/traffic relationship curve by observing the site in the next few years.

2.5 LTLF Lateral Track Strength

An assessment of track gage widening resistance was made using the Light Track Loading Fixture (LTLF). This device works by applying a lateral load to the rails (without vertical load). Deflection of the rails is measured as a change in track gage. Track locations adjacent to several ties from each of the first six test sections were measured. A mechanical failure of the device prevented further measurements in Sections 7 and 8. The results are summarized by test section and presented in Exhibit 13.

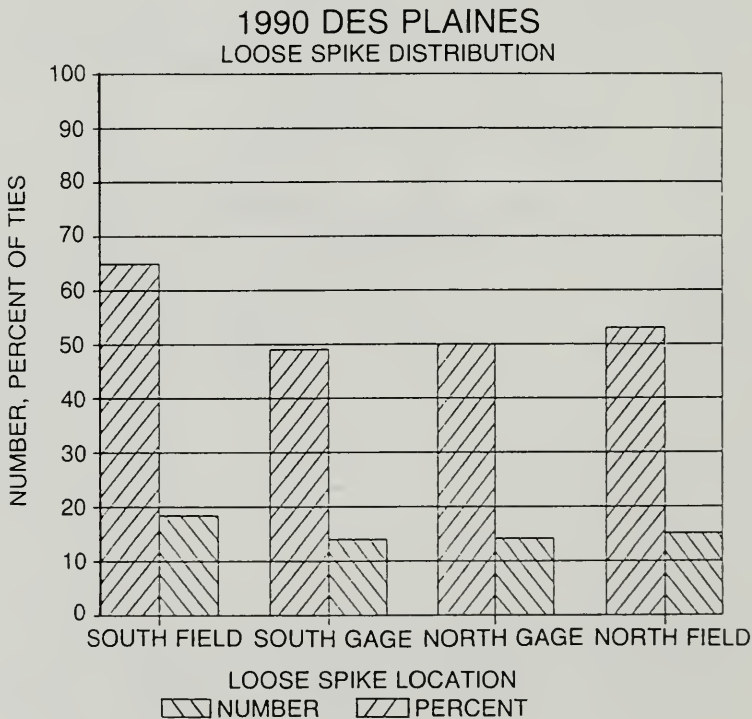


Exhibit 11. Loose Spike Location Distribution.

Test Section	Loose Spike Count					
	Ties Installed in 1988			Ties Installed in 1967		
	No. of Samples	Average (Per Tie)	Standard Deviation	No. of Samples	Average (Per Tie)	Standard Deviation
One	11	0.00	0.00	37	1.65	1.46
Two	5	0.00	0.00	43	0.63	0.92
Three	13	0.00	0.00	35	0.97	1.21
Four	13	0.00	0.00	36	0.39	0.72
Five	20	0.00	0.00	20	0.50	1.02
Six	11	0.00	0.00	33	0.42	0.78
Seven	11	0.00	0.00	22	1.14	1.39
Eight	6	0.00	0.00	35	0.91	1.30
ALL	90	0.00	0.00	261	0.83	1.19

Exhibit 12. Loose Spike Count by Test Section

Test Section	Lateral Stiffness (at 10 Kips)			Lateral Stiffness (at 6 Kips)		
	No. of Samples	Average (lbs/in)	Standard Deviation	No. of Samples	Average (lbs/in)	Standard Deviation
One	8	23343	4033	8	21667	2887
Two	8	26150	6115	8	25000	6455
Three	4	29400	4285	5	26667	7303
Four	6	29200	3510	6	26667	6667
Five	5	28320	4399	5	26667	7303
Six	7	26514	7726	8	24000	7394
Seven	3	17657	2531	4	19667	4359
Eight	0*	NA	NA	0	NA	NA
ALL	41	26071	6073	44	24333	6655

* The device failed while testing in Section 7. The severity of the failure precluded testing in Section 8.

Exhibit 13. Track Lateral (Gage) Resistance.

The results show no correlation with tie spacing; some of the stiffest sections have wide tie spacings. Factors which appear to be important are local conditions including tie condition, age, modes of deterioration, rail joint/weld location, ballast condition and failed tie clustering. Exhibit 14 shows stiffness distributions for the original and replacement ties tested. The proximity of a new tie increases lateral track strength to the 24,000 to 36,000 lbs/in range.

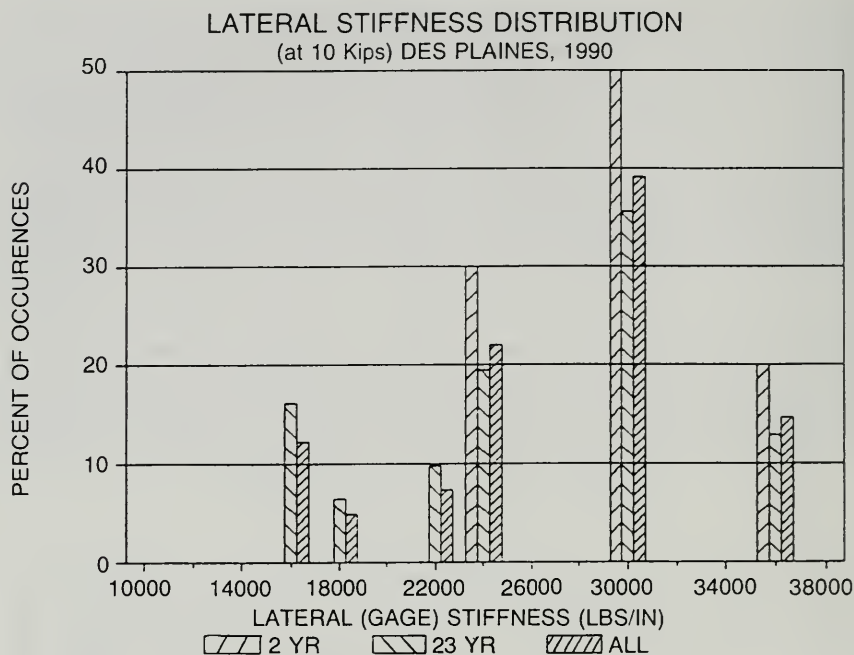


Exhibit 14. Lateral Stiffness Distribution.

2.6 Tie Renewal - Failed Tie Count

The 1990 work season brought a second tie renewal to the test site. Approximately 560 cross-ties were replaced in the tie test sections. Exhibit 15 lists the tie counts by test section. The marked ties were replaced with ties of the same dimensions; supplied by the Railway Tie Association. The only test ties which could not be replaced in kind were the 6" x 8" x 8.9' ties in Section 1. Due to the short notice given to the supplies, this unusual size could not be obtained in air seasoned stock and so, the 6" x 8" x 8.5' ties were used instead.

A second tie renewal provides more information about tie failure rates, modes and clustering. The additional data allows for revised, more confident tie life projections. Exhibit 16 lists the tie life predictions from the 1988 and 1990 tie renewal. The projections have not changed significantly except for Sections 7 and 8. The projected average life for these sections decreased 19 and 17 percent, respectively, from the 1988 projections. Fully half of the Section 7 ties were replaced in 1990.

The two sections where tie life performance has changed significantly consist of 7" x 12" x 8.5' ties. These ties appear to have reached a plate cutting maintenance threshold. Plate cutting has been the predominant mode of failure among the 7" x 12" ties. They have a large bearing area; the wider spacing (23-1/4 and 29 inches) and small tie plates (13 x 7 inches) combine to apply high pressures to the plate area.

Section Number	Tie Size Cross-Section (in x in)	Tie Length (ft)	Tie Spacing (inches)	No. Tie/mile
One	6 x 8	9	19.5	3249
Two	7 x 9	10	19.5	3249
Three	7 x 9	9	19.5	3249
Four	7 x 9	8.5	19.5	3249
Five	7 x 9	8.5	23.4	2711
Six	7 x 9	8.5	27.5	2304
Seven	7 x 12	8.5	29.3	2166
Eight	7 x 12	8.5	23.4	2711

Section Number	Number of Ties	1990 Number Removed	1990 Percent Removed	Cumm. Number Removed	Cumm. Percent Removed
One	478	116	24.27	298	62.34
Two	477	29	6.08	92	19.29
Three	477	44	9.22	160	33.54
Four	479	39	8.14	205	42.80
Five	396	22	5.56	174	43.94
Six	422	73	17.30	219	51.90
Seven	319	160	50.16	249	78.06
Eight	401	83	20.70	110	27.43

Exhibit 15. Des Plaines Tie Test Renewal Record.

Section Number	Tie Size Cross-Section (in x in)	Tie Length (ft)	Tie Spacing (inches)	No. Tie/mile	Number of Ties
One	6 x 8	9	19.5	3249	478
Two	7 x 9	10	19.5	3249	477
Three	7 x 9	9	19.5	3249	477
Four	7 x 9	8.5	19.5	3249	479
Five	7 x 9	8.5	23.4	2711	396
Six	7 x 9	8.5	27.5	2304	422
Seven	7 x 12	8.5	29.3	2166	319
Eight	7 x 12	8.5	23.4	2711	401

Section Number	1990 Number Removed	1990 Percent Removed	Cumm. Number Removed	Cumm. Percent Removed	1990 Projected Life	1988 Projected Life
One	116	24.27	298	62.34	23	24
Two	29	6.08	92	19.29	31	30
Three	44	9.22	160	33.54	27	27
Four	39	8.14	205	42.80	26	25
Five	22	5.56	174	43.94	25	24
Six	73	17.30	219	51.90	24	23
Seven	160	50.16	249	78.06	21	26
Eight	83	20.70	110	27.43	29	35

Exhibit 16. Projected Average Tie Life.

3.0 LABORATORY ANALYSIS OF SPECIMENS REMOVED FROM TRACK

In 1988, the first program renewal of ties took place. Approximately 940 ties were replaced in September of 1988 after 21 years of service. From this group, approximately 65 ties were selected for laboratory analysis during pre-renewal inspection. The 65 ties, 7-9 per section, were selected based on previous measurements. The purpose of the laboratory tests is to compare common field measurements with wood tie strength measurements. The results will indicate which, if any, field measurements are good indicators of tie strength.

During tie replacement and subsequent recovery operations, a number of the original tie selections were "lost" or destroyed during tie replacement operations. Fifty-five ties were recovered and delivered

to AAR, with 21 having field performance measurements. In 1990, a second tie renewal was performed, with approximately 560 ties being replaced. From these replaced ties a group of eighteen, 7" x 12" cross-section ties were randomly selected for mechanical testing. These ties came from test Sections 7 and 8. The main purpose of the laboratory tests of this second group is to compare the results to the 1988 tie results.

The laboratory tests consist of creosote preservative analysis and tie mechanical strength tests. The preservative analysis results are used to correlate treatment levels with tie performance and mechanical strength. The mechanical strength test results are compared with the corresponding field measurement.

3.1 Creosote Retention

The 55 specimens removed from track in 1988 and the 18 specimens removed in 1990 were analyzed for creosote retention. Samples were taken from three depth levels in the tie and analyzed. The samples were taken from the area between the rails on each tie.

Three or four, 3/4 inch diameter cores were taken from each tie. The two inch cores were cut into three pieces; the top 1/2 inch, the second 1/2 inch, and the next 1 inch. The 5 to 20 gram samples which resulted were then analyzed for moisture and creosote-type preservatives by a method similar to AWP A1-89.[10] The only difference in methods was the sample drying after toluene extraction. The use of larger (3/4 inch diameter) samples required a longer drying period (to remove the toluene) than the AWP A method required. Failure to completely dry the sample after extraction will cause an underestimation of the creosote content of the sample.

A preliminary study of the effect of sample location was conducted before the main program of sampling was started. Samples were taken from two ties in the areas shown in Exhibit 17.

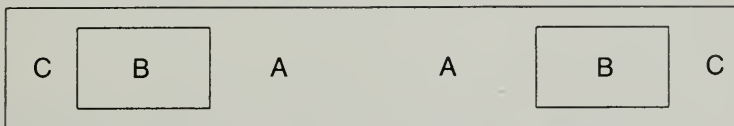


Exhibit 17. Creosote Analysis Sample Locations.

The results showed that the plate areas (B) had the highest creosote retention; particularly in the top inch. The area between the plates (A) and the ends of the tie (C) have similar creosote retention levels. The center area of the tie was chosen for all future sampling because the end area results were more variable. This was attributed to the greater permeability of wood in the longitudinal direction. The end of tie specimens were subjected to more weather/moisture related loss of creosote.

The test results were grouped by test section and tie size. The average values for each category are reported in Exhibit 18. Moisture content values are also given as determined by the analysis method. However, the values have little relevance to field moisture contents because the ties were stored indoors in a heated building for several months before the analysis. The values reflect this treatment: they are considerably lower than the values measured in track in 1987.

A histogram of creosote retention for each depth of sampling was constructed for all of the sections combined. Exhibit 19 shows the results. One may conclude from the shapes of these distributions that creosote retention levels decrease with depth into the tie. The top sample distribution is shifted to the right; indicating a higher mean and median value than the other two. This exhibit also illustrates the variability of the creosote retention seen among the samples. Values from nil to 14 pounds per cubic foot (pcf) were measured. Visual examination of the sample cores also showed the wide range of treatment retention levels.

Comparison of creosote retention results between ties removed in 1990 and 1988 revealed a marked decrease in average creosote retention throughout the two inch depth examined. The 1990 results had no

Test Group		Creosote 0-0.5" (PCF)	Moisture Content (Percent)	Creosote 0.5-1.0" (PCF)	Moisture Content (Percent)	Creosote 1-2" (PCF)	Moisture Content (Percent)
1988	AVG (55)	3.55	7.20	2.77	7.35	2.13	9.29
	STD	2.72	2.38	2.69	3.03	2.16	4.25
	MIN	0.00	1.97	0.00	0.00	0.00	4.38
	MAX	11.34	13.12	13.38	15.52	11.38	21.68
1990	AVG (18)	2.30	8.46	1.93	10.52	1.65	22.70
	STD	0.90	2.31	0.95	4.18	1.16	10.26
	MIN	0.03	4.81	0.05	5.15	0.00	9.07
	MAX	3.92	12.29	3.38	23.98	4.07	41.60
Average Values By Test Section							
One	(8)	1.79	6.59	1.46	5.85	1.17	7.11
Two	(7)	3.36	7.03	2.52	6.54	1.70	7.83
Three	(6)	3.68	7.13	2.96	7.27	3.02	9.49
Four	(6)	6.64	7.52	5.27	7.98	4.11	10.62
Five	(8)	3.46	7.57	2.79	8.17	2.25	8.47
Six	(7)	2.57	5.45	1.37	5.78	1.16	8.04
Seven	(4)	2.80	8.45	1.54	10.10	1.44	13.43
Eight	(4)	2.40	8.65	2.16	8.69	0.78	12.27
Average Values By Tie Size							
6 X 8	(8)	1.79	6.59	1.46	5.85	1.17	7.11
7 X 9	(34)	4.17	7.39	3.24	7.64	2.64	9.21
1988 7 X 12	(8)	2.56	7.39	1.71	7.86	1.14	10.93
1990 7 X 12	(18)	2.30	8.46	1.43	10.52	1.65	22.70
7 X 9 X 10	(8)	3.36	7.03	2.52	6.54	1.70	7.83
7 X 9 X 9	(7)	3.68	7.13	2.96	7.27	3.02	9.49
7 X 9 X 8.5	(19)	4.10	6.81	3.04	7.27	2.43	8.97

Exhibit 18. Average Creosote Retention by Test Section/Category.

sample with retentions above 5 pcf. The differences between the two groups is greatest at the surface level 0-0.5 inches. The difference in average creosote retention between the two groups was quite unexpected, since the ties were all treated at the same time. The ties with high creosote retentions were studied more closely. Exhibit 20 shows a plot of creosote retention vs. tie number. The ties with highest creosote retentions are clustered in Sections 4 and 5. Sections 4, 5 and 6 have the conventional (CNW standard) 7" x 9" x 8.5' ties. Early progress reports^[1-6] discuss site inspectors finding some (100-200) 7" x 9" x 8.5' ties which are not original test ties. The personnel involved speculated that one carload of 7" x 9" test ties was inadvertently swapped with a carload of CNW standard ties. The most obvious difference between the swapped ties and the test ties are the species. Also, the swapped ties are slightly narrower; some may be 7" x 8".

DES PLAINES TIE TEST CREOSOTE RETENTION BY DEPTH IN TIE REMOVED 1988

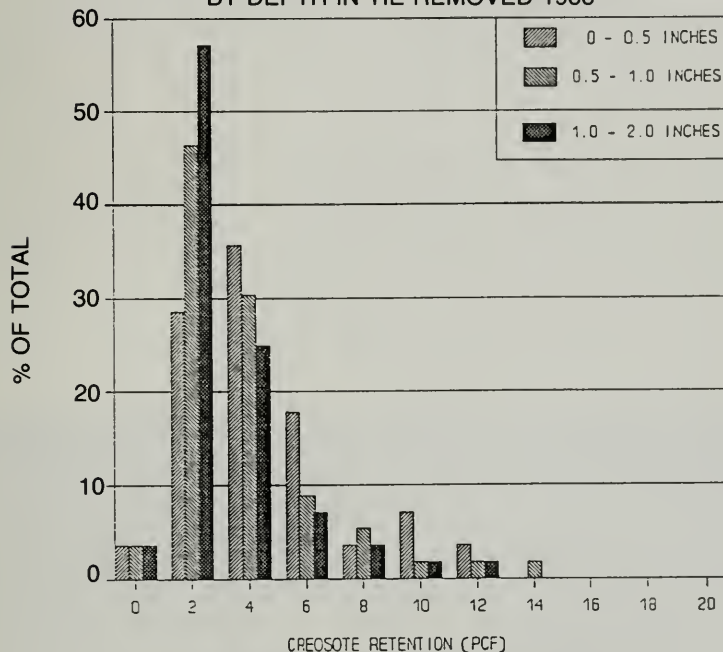


Exhibit 19. Creosote Retention Distribution.

The swapped ties appear to be mostly gum; whereas, the test ties are red and white oak. Species identification of the 55 ties removed in 1988 revealed the following distribution:

Species	Number	Percentage of Total
Red Oak	34	64
White Oak	9	17
Gum	10	19

Nine of the ten gum ties were 7" x 9" specimens. The tenth was one half of a 7" x 12" dowel-laminated tie. Elimination of the gum ties from the 1988 tie population would lower the average creosote retention values. It is no longer possible to separate the data in this way due to loss of identification tags between the time the creosote retention testing and the species identification was done. Historically, gum ties have higher treatment retention levels than oaks. The few samples which were identified as gum also were among the ties with the highest creosote retention levels.

A direct comparison of 7" x 12" ties removed in 1988 and 1990 shows little difference in treatment retention levels. Since these are virtually all oak ties, the comparison is relevant. The large difference in moisture content in the second inch level between the 1988 and 1990 samples is due to their different length of storage time. The 1988 samples had sufficient time between removal from track and laboratory testing to dry beyond the two inch depth. The 1990 samples, however, were in storage a shorter time; they have not dried out at the two inch level.

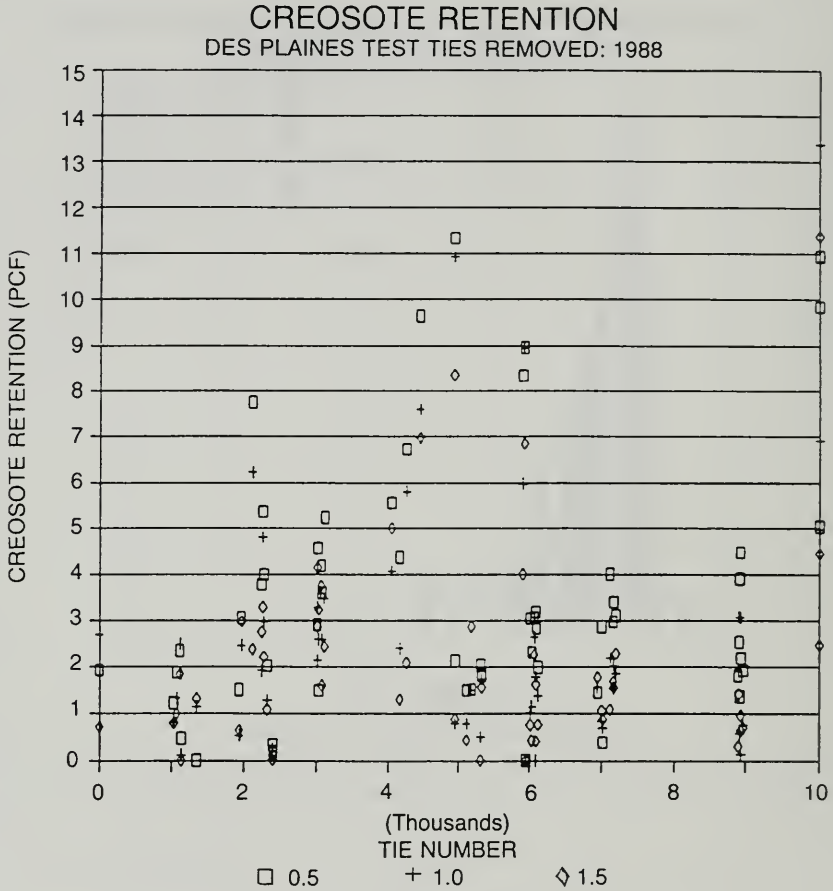


Exhibit 20. Creosote Retention vs. Tie Number.

3.2 Mechanical Properties

The 55 ties removed from track in 1988 and the 18 ties removed in 1990 were also tested for mechanical strength using standard tests developed for railroad ties.^[10] The tests consist of three point bending (5 foot span), compression modulus, surface hardness, density, and spike push-pull tests.

These tests measure the ability of the tie to perform its primary functions of rail support and gage restraint. An assessment of the loss of strength vs. time and/or tonnage may also be made by assuming a nominal new tie strength value. One long term goal of this study is to improve the ability of visual inspection to select ties which are no longer capable of performing satisfactorily.

3.2.1 Bending Modulus

The ties selected for creosote analysis were also used in the mechanical strength tests. These ties were subjected to a full span three pointing bending test.^[11] Exhibit 21 shows the test configuration.

Exhibit 22 shows the load-deflection curve for tie number 6035, a typical specimen. Typical specimens showed some residual deflection a few hours after testing.

Bending modulus of elasticity (M.O.E.) was calculated for each specimen using the actual tie dimensions. The modulus values were calculated from loads and deflections obtained after a 1000 lb. "seating" load was applied. This assumed that tie surface and/or plate discontinuities did not materially affect the results.

Tie stiffness was also calculated as the load per inch of deflection. Both tie stiffness and bending M.O.E. are listed in Exhibit 23. Tie vertical stiffness varies less than M.O.E. between the eight test sections. Vertical stiffness is a better indicator of in-track performance. Still, the differences in tie mechanical properties are substantial. The difference in stiffness is related to tie cross-section. The 6" x 8" ties and the 7" x 12" ties were considerably less stiff; with 70 to 80 percent of the average value (See Exhibit 24). The 7" x 12" ties are actually two 7" x 6" pieces that are mechanically joined.

The modulus values calculated from the load/deflection data reflect the stiffness of the tie and the size of the tie, too. The 7" x 12" ties have modulus values of only 40 to 45 percent of the average value; whereas, the 6" x 8" ties have modulus values well above (120%) the average value.

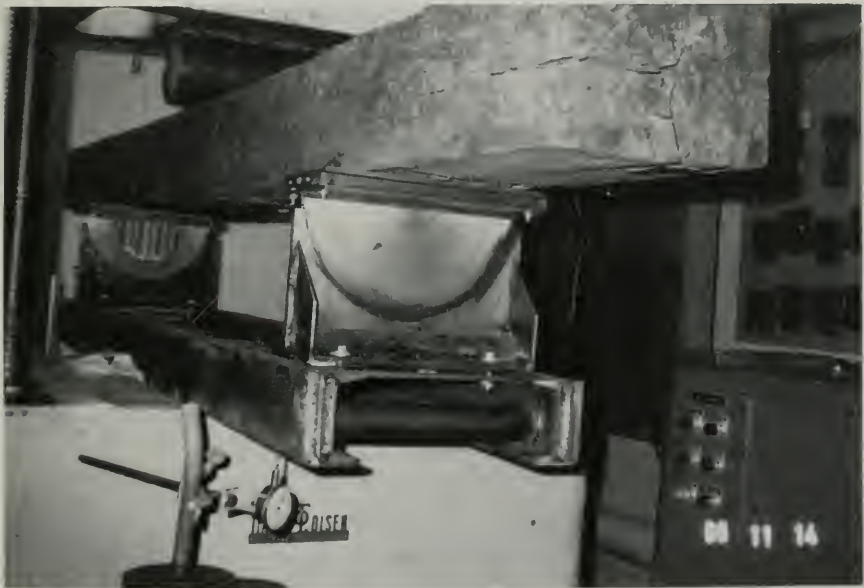


Exhibit 21. Tie Bending Test Set-up.

The tie cross-section is the major factor in these differences. Other factors may include: local rail, tie condition or mode of failure, and local support conditions. Tie length is not a relevant factor in this bending test because of the test configuration (i.e. a three point loading at a fixed span length). The tie is supported in the railseats and loaded in the center.

The bending modulus values calculated for the 7" x 12" ties removed in 1990 were considerably higher than the values recorded for the 1988 ties. The 1990 average value of 366,000 psi is 67 percent above the 1988 average value of 219,000 psi. While the 1990 sample was much larger (18 ties vs. 8 ties), the standard deviations were similar in magnitude (76,000 vs. 56,000). Tie stiffness values were also higher in the 1990 ties.

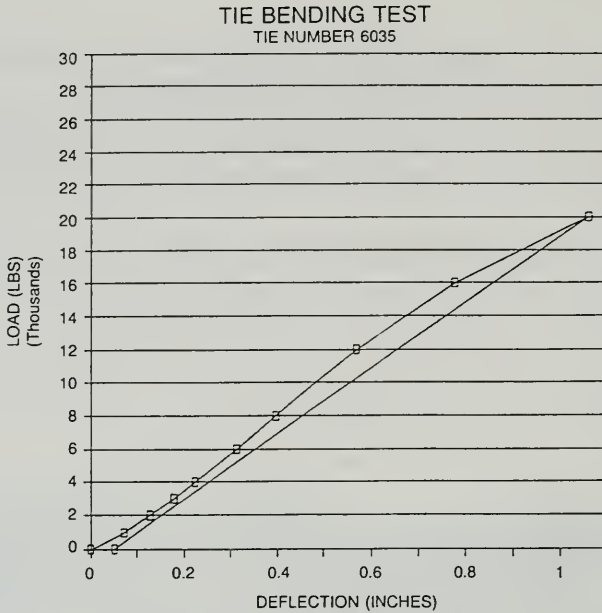


Exhibit 22. Example Tie Bending Data.

Test Group	Bending Stiffness at Elastic Limit (lbs/in)			Bending M.O.E. (lbs/in/in)	
	Count	Average	Std Dev.	Average	Std Dev.
1988					
One	7	21724	5505	678865	172029
Two	6	32190	12786	563086	223663
Three	6	31097	8364	543975	146312
Four	8	26617	8456	465598	147918
Five	7	44135	22610	772038	395508
Six	7	30974	8333	541819	145770
Seven	4	25044	6926	220116	60872
Eight	4	24791	5762	217886	50643
ALL	49	29996	13396	532004	265740
6 x 8	7	21724	5505	678865	172029
7 x 9	34	32895	14638	575416	256057
7 x 12	8	24917	6372	219001	56003
7 x 12'	18	30628	5968	365908	78583

This group of ties was removed in 1990 during the second tie replacement. All others tested were removed in 1988 during the first tie replacement.

Exhibit 23. Bending Test Results Summary.

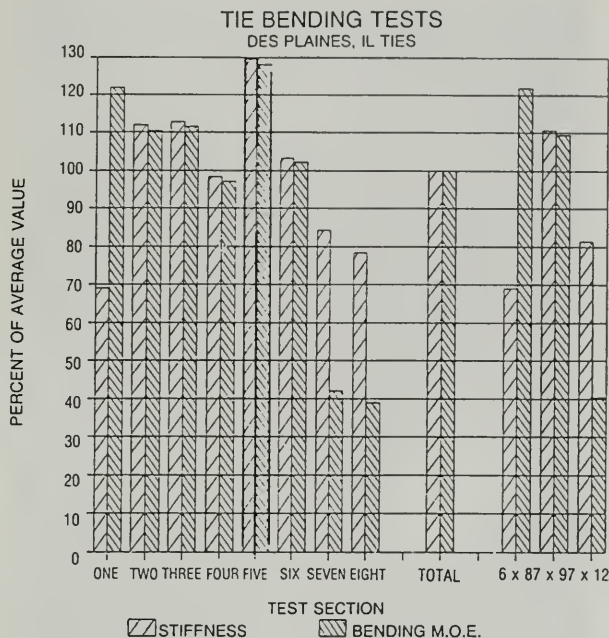


Exhibit 24. Comparison of Test Section Tie Bending Performance.

3.2.2 Compression Modulus

A number of the ties were subjected to Compression Perpendicular to the Grain Load tests. This test determines the crushing capacity of the wood in the critical rail seat area. This is the area of the tie that is prone to failure in severe service environments. Additional compression tests were administered to non-rail seat areas for comparison purposes. Exhibit 25 shows the test configuration.

A 24,000 lbs. load is applied through a movable crosshead and carried through a short section of 115 RE rail to a 7.75" x 13' tie plate and in turn to the upper surface of the cross-tie at right angles to the length. The rate of loading of the movable crosshead is 0.024 inch per minute.

The results of the compression testing are listed in Exhibit 26. The compression of the ties in the rail seat area, at a given load, is considerably higher than in the non-rail seat areas. There is an average of a 46 percent increase in modulus of compression values when the measurement is taken in an area which was not directly exposed to loading (i.e. rail seat area). This increase can be attributable to mechanical breakdown of the tie due to loading and also to an increased amount of biological breakdown which occurs in the rail seat area under the tie plate. The data also suggests that this difference in degradation under the tie plate is not as prominent for the 7" x 12" cross-section dowelled specimens. The reduction in compression modulus, as a percentage of the difference between the two values, underneath the tie plate for the dowelled ties is approximately half of that for the smaller cross-section, one piece ties (Exhibit 27). This may be due to the extra support gained by utilizing the greater width of the dowelled ties.

Exhibit 28 shows the average compression modulus values for each test section. There does not appear to be any consistent correlation throughout the sections between compression modulus and cross-sectional areas for the limited amount of samples tested. Increased tie spacing, which can be best represented by Sections 4 (19.5 inch spacing), 5 (23.4 in.), and 6 (29.3 in.) shows no apparent correlation with compression modulus for the limited number of samples taken. Decreased tie length which can be represented by Sections 2 (10 foot length), 3 (9 ft.), and 4 (8.5 ft.) also shows no apparent correlation with compression modulus for the samples taken.



Exhibit 25. Compression Modulus Test Configuration.

Tie Plate Area Compression Modulus (PSI)				Non-Tie Plate Area Compression Modulus (PSI)		
Section	Count	Average	Std. Dev.	Count	Average	Std. Dev.
One	8	7479	3490	7	11689	2382
Two	3	9150	3756	3	11535	2071
Three	2	6778	38	2	10710	1030
Four	2	9290	710	2	14465	2435
Five	3	11307	2137	4	15190	4361
Six	2	7520	480	2	10275	1575
Seven	2	9290	2410	6	10800	2237
Eight	2	8978	933	3	11990	1747
ALL	39	8358	3308	42	12199	3255
6 X 8	8	7479	3490	7	11689	2382
7 X 9	26	8482	3433	25	12597	3696
7 X 12	5	9123	1640	10	11560	2322

Exhibit 26. Compression Modulus Results.

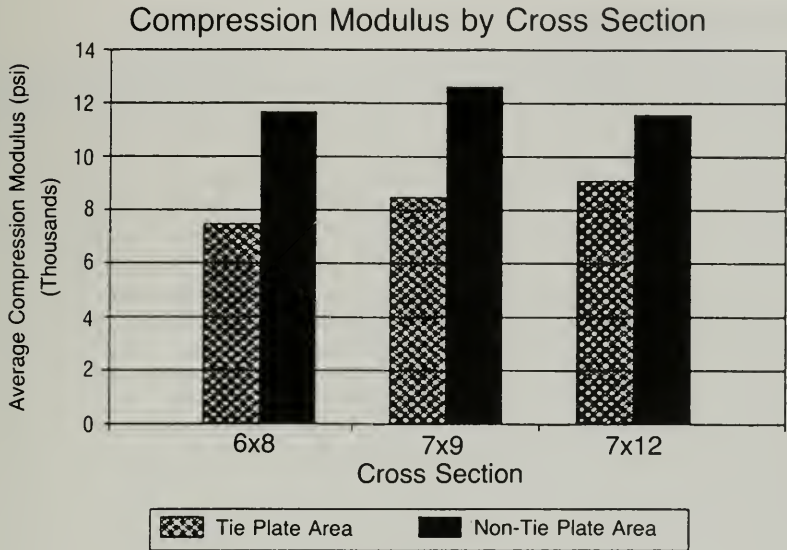


Exhibit 27. Compression Modulus by Cross-Section.

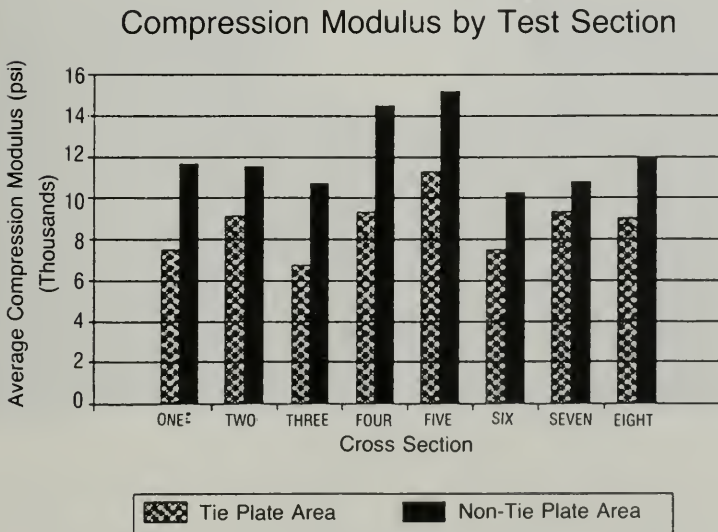


Exhibit 28. Compression Modulus by Test Section.

3.2.3 Surface Hardness Test

The same ties used in the compression modulus test were also subjected to a Surface Hardness test. This test was used to define the surface hardness of the tie specimen in the critical plate area as well as in the non-plate area for comparison purposes. It is hypothesized that the surface hardness test may correlate directly with tie plate cutting resistance of the specimens. Exhibit 29 shows the test configuration.

The test is run using a 2 inch diameter steel ball which is pushed down into the tie area to be tested. The test is conducted at a speed of 0.25 inches of crosshead deflection per minute. The maximum load required to embed the ball 0.25 inches into the specimen is the measure of surface hardness (lbs.). The slope of the straight line portion of the load penetration curve is the hardness modulus (lbs./inch).

The results of the Surface Hardness tests are listed in Exhibit 30. Similar to the Plate Compression test results, the Surface Hardness in the tie plate area is significantly diminished compared to the non-plate area results. In addition to the detrimental biological and loading effects, another contributing factor for this phenomena may be in the seclusive point loading of this procedure. Unlike the compression modulus tests which utilize the full tie plate as a loading area, the surface hardness test has a single point loading area which is very susceptible to slight variations in the wood surface which is usually very heterogeneous in a worn tie. Converse to the Compression Modulus results, the differences between the two regions of testing is greatest for the crossties with the largest cross-sectional areas. There is an increase in Surface Hardness on the non-rail seat area tests (with respect to the rail seat area tests) of 120%, 114%, and 187% for the 6" x 9", 7" x 9", and the 7" x 12" cross-sections respectively (Exhibit 31). No positive correlation between an increased cross-sectional area and surface hardness exists for either the plate or non-plate area of the specimens.

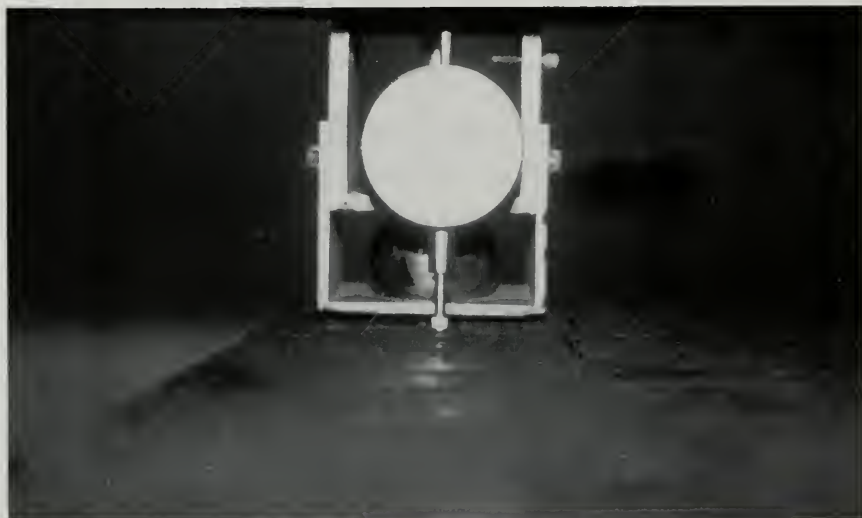


Exhibit 29. Surface Hardness Test Configuration.

Tie Plate Area Hardness (LBS)				Non-Tie Plate Area Hardness (LBS)		
Section	Count	Average	Std. Dev.	Count	Average	Std. Dev.
One	8	1143.75	875.16	7	2514.29	525.57
Two	3	1425.00	480.02	3	2066.67	589.26
Three	2	1190.00	690.00	2	2600.00	50.00
Four	2	975.00	325.00	2	1775.00	325.00
Five	3	1500.00	604.15	4	2250.00	609.30
Six	2	375.00	75.00	2	2450.00	550.00
Seven	2	1175.00	425.00	6	1891.67	434.37
Eight	2	585.00	415.00	3	2566.67	619.59
ALL	39	1024.74	667.04	42	2260.83	589.87
6 X 8	8	1143.74	875.16	7	2514.29	525.57
7 X 9	26	1039.81	600.76	25	2226.20	588.79
7 X 12	5	756.00	521.79	10	2170.00	587.45

Exhibit 30. Surface Hardness Results.

Exhibit 32 shows the average surface hardness values for each of the test sections. An increase in tie spacing would produce higher rail seat loadings, thus, theoretically doing a greater amount of damage in the tie plate area of the specimens. The trend for increasing tie spacing (Sections 4, 5, and 6) shows that there is no correlation with surface hardness for these specimens. Sections 2, 3, and 4, which represent a decrease in tie length for the same time spacing and cross-sectional area, does show a decrease in surface hardness with respect to decreasing tie lengths. The limited amount of samples makes any speculation of trends preliminary at best.

3.2.4 Crosstie Density

Density measurements were run on all of the specimens subjected to the physical tests (tie plate area and non-tie plate area). Crosstie density is a good measure of the soundness or the solidity of a specimen. Decay, checks and splits, and moisture content are all factors which can have significant effects on a measured density.

The results of the density measurements are listed in Exhibit 33. They are also illustrated by test section (Exhibit 34) and by cross-section (Exhibit 35). A typical new crosstie has an average density of 60 lb./cu. ft.. All of the average densities for the various test sections and cross-sections are in the range of 47+ / - 4 pcf. This represents a decrease in density of approximately 20% over the 22 year life of the ties. The variance between the test sections and cross-sections appears to be insignificant at this time.

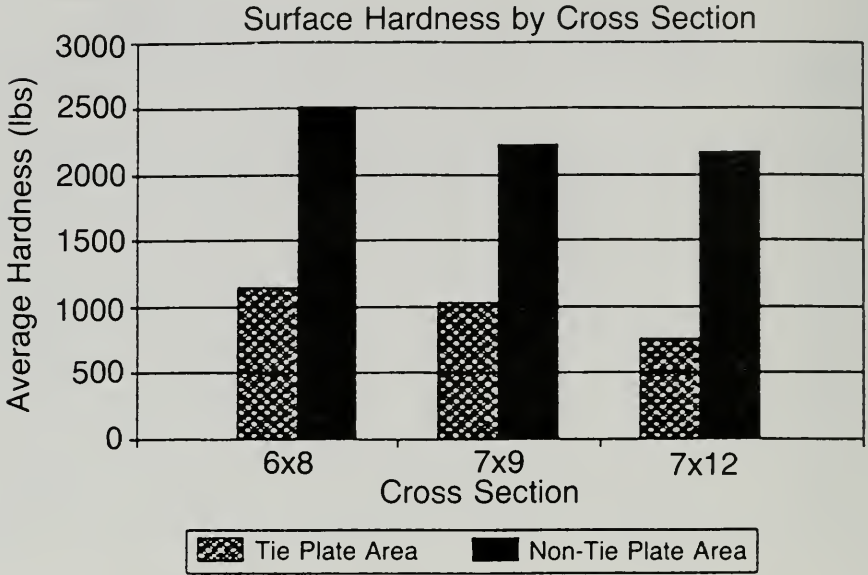


Exhibit 31. Surface Hardness by Cross-Section

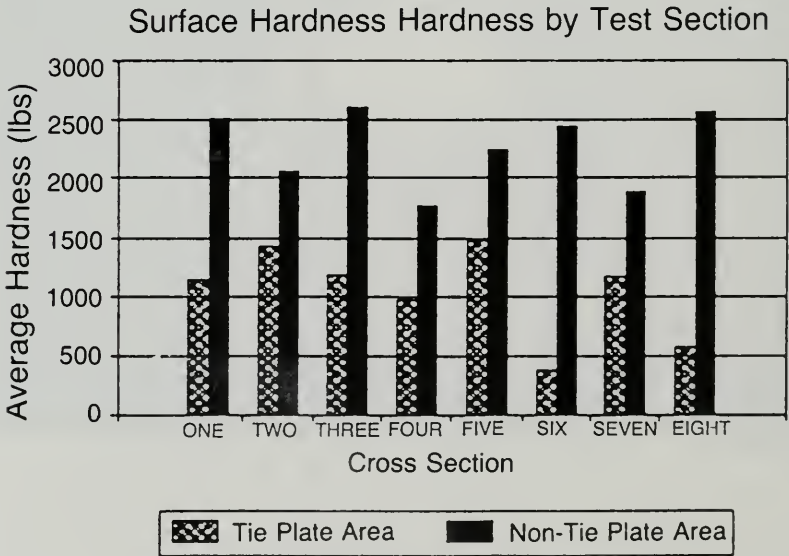


Exhibit 32. Surface Hardness by Test Section.

Tie Plate Density (PCF)				Non-Tie Plate Density (PCF)		
Section	Count	Average	Std. Dev.	Count	Average	Std. Dev.
One	8	46.00	2.78	7	43.57	3.42
Two	3	49.00	4.24	3	46.67	4.78
Three	2	47.00	2.00	2	47.00	3.00
Four	2	48.50	3.50	2	46.00	5.00
Five	3	43.33	6.94	4	44.75	3.77
Six	2	47.50	0.50	2	46.00	2.00
Seven	3	48.00	2.16	5	51.00	1.67
Eight	2	44.50	1.50	3	45.33	2.49
ALL	42	46.83	3.79	41	45.54	4.18
6 X 8	8	46.00	2.78	7	43.57	3.42
7 X 9	26	46.65	4.14	25	45.04	4.09
7 X 12	8	48.25	2.99	9	48.44	3.44

Exhibit 33. Crosstie Density Results.

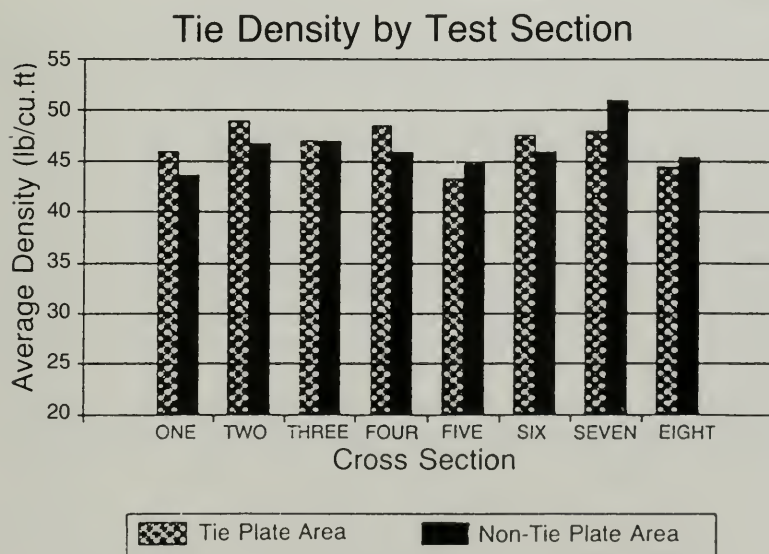


Exhibit 34. Crosstie Density by Test Section.

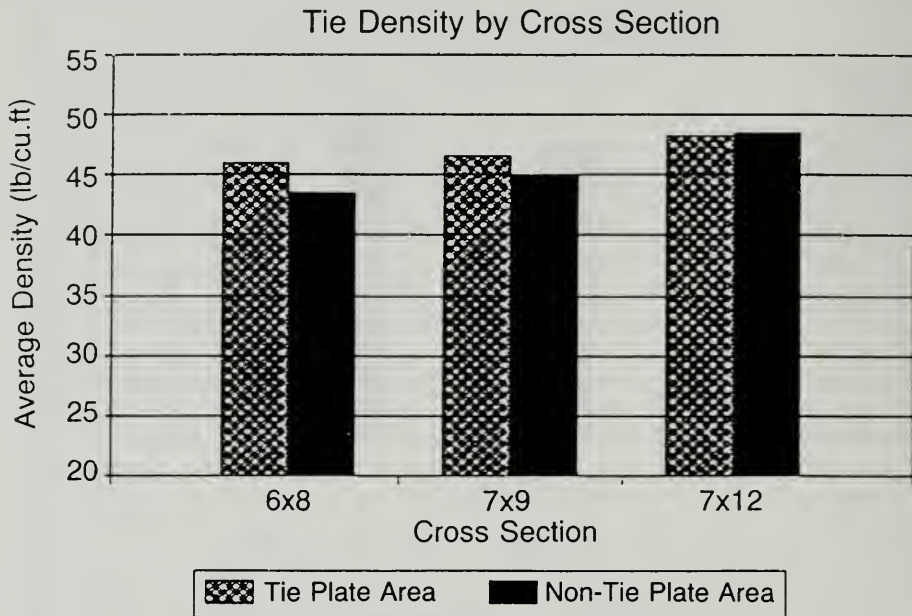


Exhibit 35. Crosstie Density by Cross-Section.

3.2.5 Spike Resistance Tests

Spike Resistance tests are used to indicate the rail gage and rollover restraint capacity of the tie/fastener system. Spike drive-in force, withdrawal force, and lateral resistance are measured for each of the specimens. The results are listed in Exhibit 36, and portrayed by cross-section in Exhibit 37.

A new 5/8" square and 6-1/2" long cut-spike is inserted into the pre-bored (1/2") plate area of the tie to be tested. The spike is inserted at the rate of 2 inches per minute. The maximum force required to push the spike down into the tie is recorded. This force will be referred to as the "drive-in" force.

A typical drive-in force for a new oak crosstie is approximately 9700 lbs. The average values seen for these 22 year old ties range from 6484 lbs for the 7" x 9" cross-sections to 7300 lbs for the 6" x 8" cross-sections, with a high of 7904 lbs for the 7" x 12" cross-section ties. This represents an average loss of between 18% and 33% of the typical new tie values. Analysis of the individual test sections reveals that there does not appear to be any consistent trend with respect to the individual cross-sections. The variability within any given test section or cross-section is large enough to mask any differences which may exist between the groups.

The spike is withdrawn from the tie at a rate of 0.3 inches per minute. The maximum force required to completely remove the spike in plane normal to the tie surface will be referred to as the "withdrawal" force. Exhibit 38 shows the configuration used for the withdrawal test.

SPIKE RESISTANCE

Section	Count	Drive-In (LBS)	Std. Dev.	Withdrawal (LBS)	Std. Dev.	Lateral Resistance (LBS)	Std. Dev.
		Average		Average		Average	
One	4	7300	2528	5205	2712	1664	349
Two	3	7088	3149	3820	3550	1790	1312
Three	2	5460	580	2300	1060	1040	245
Four	2	6470	1670	4800	700	1665	5
Five	3	7680	1367	5433	985	1968	206
Six	2	7400	1740	4690	1610	1298	73
Seven	1	13320	0	8080	0	1750	0
Eight	2	5890	2010	1660	1140	1433	218
ALL	28	6780	2229	3926	2371	1472	670
6 X 8	4	7300	2528	5205	2712	1664	349
7 X 9	19	6484	1863	3879	2178	1506	711
7 X 12	5	7904	3110	3144	2623	1143	516

Exhibit 36. Spike Resistance Results

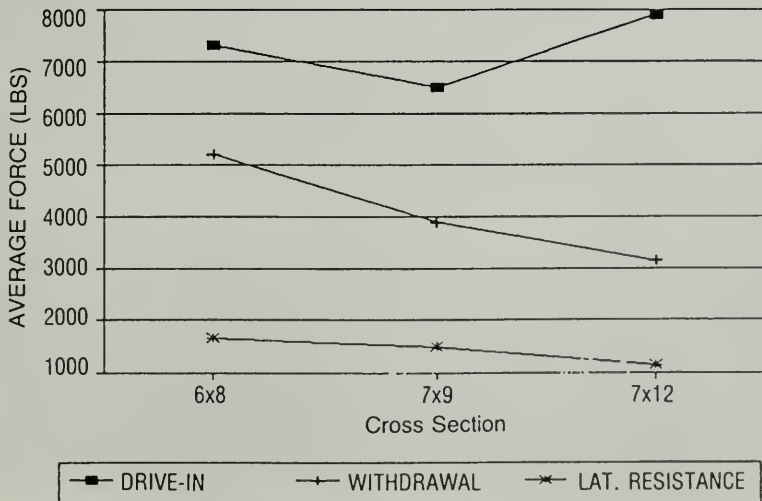
SPIKE RESISTANCE
DES PLAINES IL. TIE TEST

Exhibit 37. Spike Resistance by Cross-Section

A typical withdrawal force for a new oak crosstie is approximately 8800 lbs. The average values seen for these 22 year old crossties range from 3144 lbs for the 7" x 12" cross-sections to 3879 lbs for the 7" x 9" cross-sections, with a high of 5205 lbs for the 6" x 8" cross-section ties. This represents a loss of between 41% to 65% of the typical new tie values. This data may suggest that the larger cross-sectional areas have decreasing withdrawal forces, but as with the previous data, the scatter of the values is much too great to draw such a conclusion.

Each crosstie is unique, therefore, if we look at each crosstie's withdrawal force (or average of a group) with respect to the particular crosstie's drive-in force, meaningful trends may be developed. A new oak crosstie would have a ratio of 8800lb/9700lb, or a withdrawal force which is 91% of the drive-in force. Theoretically, a reduction of this ratio would occur as the crosstie ages and loses some of its ability to hold down spikes. The 22 year old ties as a whole have a ratio of 67%. The 6" x 8" cross-sections have a ratio of 71%. The 7" x 9" cross-sections have a ratio of 60%. The 7" x 12" cross-sections have a ratio of 40%. This data does suggest that the larger cross-sections, along with their various tie spacings, are degrading at a more severe rate than the smaller cross-sections and their corresponding tie spacings. This may be in part due to an increased dimensional stability of the smaller cross-section crossties. This increased dimensional stability is primarily attributable to a reduced moisture gradient which exists in the smaller crossties. Another factor which should not be overlooked, is the fact that all of the 6" x 8" cross-sections are from a single section which has a nominal tie spacing of 19.5 inches. All of the other cross-sections are incorporated into at least some sections which have wider spacings. These wider spacings translate into greater transmitted loads as seen by each individual crosstie, therefore causing a greater degree of mechanical breakdown. The physical condition of the tie could have a large effect on the ratio. A tie which is severely deteriorated could lead to misleading calculations, for example, a tie with a very low drive-in force and a comparable low withdrawal force may not have a poor index rating. Therefore, the absolute values of the force measurements must be taken into account as to negate any atypically bad ties.

The "Lateral Spike Resistance" is the force required to displace or bend the spike head 0.2 inches laterally while the spike is inserted in the crosstie. The load is applied parallel to the tie surface and at a rate of 0.1 inches per minute. Exhibit 39 shows the configuration used for the lateral resistance test.

A typical lateral spike resistance for a new oak crosstie is approximately 2800 lbs. The average values seen for these 22 year old crossties range from 1143 lbs for the 7" x 12" cross-sections to 1506 lbs for the 7" x 9" cross-sections, with a high of 1664 lbs for the 6" x 8" cross-section ties. This represents a loss of between 41% to 59% of the typical new tie values. When compared to the individual tie drive-in values, a new oak tie would have a lateral resistance/drive-in force ratio of 29%. The 22 year old crossties as a whole have a ratio of 22%. The 6" x 8" cross-sections have a ratio of 23%. The 7" x 9" cross-sections have a ratio of 23%. The 7" x 12" cross-sections have a ratio of 14%. This data also suggests that the larger (7" x 12") cross-sections, along with their corresponding tie spacings are degrading at a faster rate than the other crossties at their particular spacings.

4.0 DISCUSSION

The results of the field performance measurements provide a great deal of information on the performance of ties. Comparisons of ties installed in 1967 and in 1988 show important differences in performance. These differences provide insight into the mechanisms of tie deterioration.

The moisture content of the tie changes from the time it is installed until it is removed. Newer ties, represented by the two year old 1988 ties, have a higher average moisture content than older ties, represented by the 23 year old 1967 ties. From the time a tree is harvested and crossties are cut until the crossties are treated with preservative, the wood decreases in moisture contents from 100-200% to 40-60%. This moisture content is still higher than most ties in the field, indicating that drying also occurs in-track. The shape of the data distributions also indicate changes in tie performance. The new ties have a symmetrical and widely dispersed distribution about the mean value of 36 percent. The older ties have a

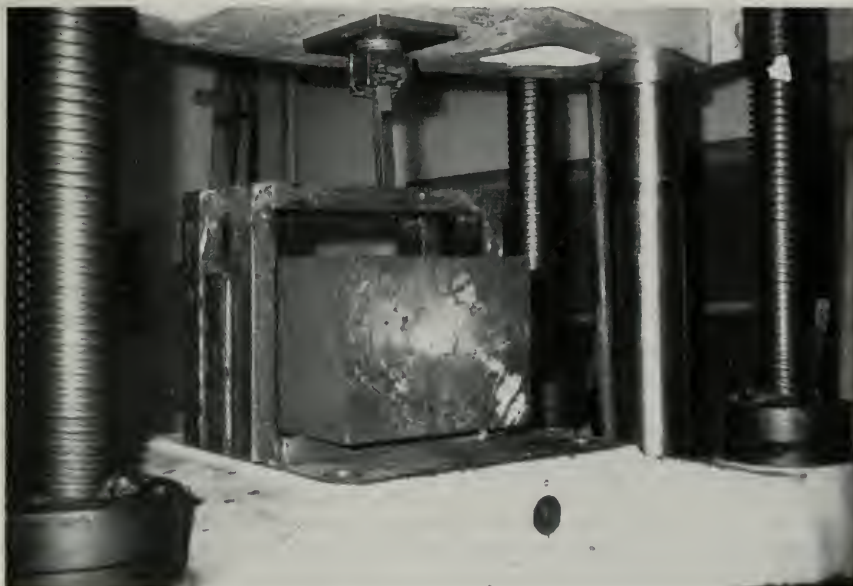


Exhibit 38. Spike Withdrawal Test Configuration.

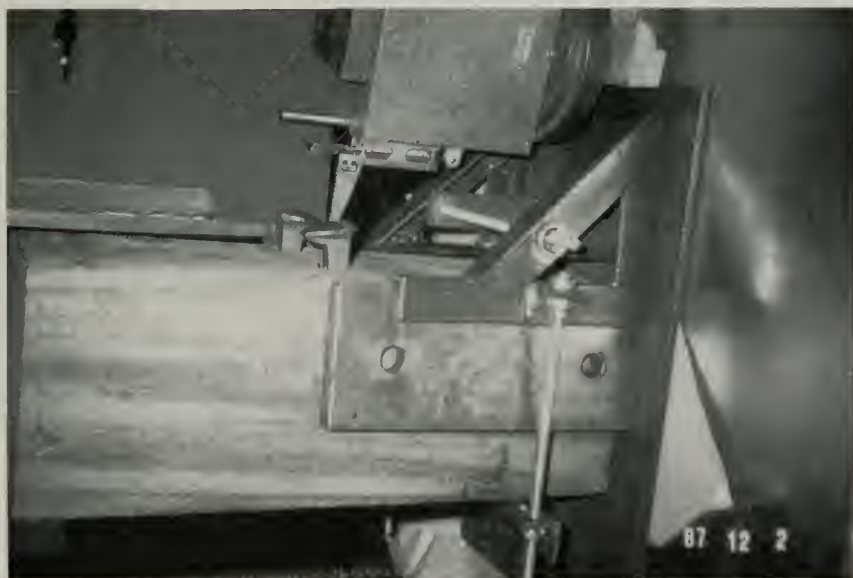


Exhibit 39. Spike Lateral Resistance Test Configuration.

mean value of 32 percent and a non-symmetrical distribution which is skewed to the left (i.e. lower values) most of the data falls in a narrower range near the mean value. There is also a "tail" of high moisture content ties. The large body of data near the mean value represents good ties. They are drier than the newer ties. The tail of high moisture contents represent ties with incipient and/or active decay. Their performance may or may not be affected by the decay at this stage.

The plate cutting measurements also reveal information about tie deterioration. Comparison of measurements from ties installed in 1988 and ties installed in 1967 show that there is a high rate of "cutting" in the first two years (compared to the long term average rate in the 1967 ties). This initial rate of 0.04 inches per year is about twice the long term rate of the 1967 ties.

This phenomenon may be due to several factors. One is a "cutting-in" period. The tie plate/tie surface contact area may be mismatched at first. As the tie wears or deforms to a more conformal contact, a large rate of "plate cutting" results. Wood compression due to loading also has a high initial rate that tapers off over time. Another factor which may account for the high initial rate of plate cutting is the variability of tie plate thicknesses. The reference point used for all plate cutting measurements is the theoretical "no plate cutting" point. This is determined by adding the tie plate thickness to the zero point of the measuring device. No initial reference point was actually measured for each tie. If the plate thickness used was too large, one would have higher than actual plate cutting values. However, we have no reason to believe that the plate thickness used is in error.

Both the newer and original ties show a tilting of the tie plates to the left (in the direction of traffic). This is assumed to be due to local conditions at the site. Previous inspections have shown the left rail is lower than the right throughout the test sections.

The loose spike survey results were also quite illuminating. No loose spikes were found on 90 ties installed in 1988. However, over 40% of the ties installed in 1967 have at least one loose spike. This result suggests that a time or traffic dependent factor is involved. The even distribution of loose spikes across the tie also suggests that an environmental factor is important in this failure mode. Whether it is local decay (i.e. bacteriological) or iron degradation (i.e. chemical) is not known. It may be strictly wood fatigue, without significant effects from these other factors.

Previous tie life projections made with the Forest Products Curve were mostly confirmed as accurate by the 1990 tie renewal counts. The only exceptions were with the 7" x 12" ties in Sections 7 and 8. Heavier than expected replacements have lowered the average life projections by five and six years respectively. The severe plate cutting and subsequent plate area deterioration on these ties has reached a maintenance limit.

Creosote retention analysis on ties installed in 1967 shows a wide range of creosote in the ties. Some of the variation is due to species effects with gums on the high and white oaks on the low side of average. Virtually all of the ties have measurable creosote. Generally, creosote retention was lower in the second inch of depth than in the first.

The 7" x 12" ties do not behave the same as the solid sawn 7" x 12" ties would. The bending modulus values are considerably lower than the 7" x 9" ties or the 6" x 8" ties. The stiffness values are slightly above the 6" x 8" ties and about 20% lower than the 7" x 9" ties. Two reasons are postulated for the low test results. First, the mechanical efficiency of the joint (i.e. the dowels) is very low. Second, the severe plate cutting may have allowed decay to occur more extensively in these ties by allowing exposure of untreated wood. And, the deteriorated wood is much weaker in strength.

The low mechanical efficiency of the joint in the 7" x 12" ties is the likely reason for the low bending modulus values. The density of the wood in the 7" x 12" ties is higher than the density in the 6" x 8" and 7" x 9" ties. Thus, the ties are probably not to any extent more deteriorated than the others.

Analysis of the compression modulus and surface hardness tests, reveal that the ties are deteriorating at an accelerated rate underneath the tie plates, with respect to the other portions of the tie. The compression modulus values in the tie plate area average 46% less than the non-tie plate area values. However, these mechanical property tests do not show that there are significant differences between the various size ties.

The 7" x 12" ties do appear to be losing their spike holding capabilities at a faster rate than the 7" x 9" and the 6" x 8" ties. This is most likely due to the decrease in dimensional stability and the large average tie spacing of the 7" x 12" ties.

5.0 RECOMMENDATIONS FOR FURTHER RESEARCH

While a very small sample of mechanical strength data has been collected from testing replaced ties, it is not sufficient to develop the relationships between field performance and mechanical properties.

In order to obtain the information required, the following steps should be taken prior to the next tie renewal:

- Another battery of in-track tie performance measurements: gage, crosslevel, plate cutting, LTLF, and moisture content on a 10% sample.
- Characterization of the track load environment. By measuring forces at the railhead, one may determine the relationship between loading and tie performance. By measuring loads at two tie spacings, the effect of tie spacing on load distribution can be studied.
- Characterization of Track Lateral Strength. The AAR Track Loading Vehicle (TLV) can provide a good characterization of loaded lateral track strength. By testing dynamic gage widening, a good assessment of tie performance/condition may be made. The TLV should test the test sections and 1/2 mile beyond in both directions.
- Selection of 8-10 ties from each test section for mechanical testing. These ties will be selected on the basis of their current condition and their past performance test data. This will ensure that enough data will be available to compare field and laboratory results.

After the next tie renewal the following step should be taken:

- In-track tie performance measurements. Measurement of gage, crosslevel, and LTLF will allow us to assess the benefits of tie replacement on track performance.

6.0 REFERENCES

1. Magee, J. and Somogy, C., Progress Reports of Cooperative Research on Wood Ties of the Railway Tie Association and Association of American Railroads Research and Test Department, Association of American Railroads, 1966.
2. Magee, J. and Somogy, C., Progress Reports of Cooperative Research on Wood Ties of the Railway Tie Association and Association of American Railroads Research and Test Department, Association of American Railroads, 1967.
3. Magee, J. and Somogy, C., Progress Reports of Cooperative Research on Wood Ties of the Railway Tie Association and Association of American Railroads Research and Test Department, Association of American Railroads, 1968.
4. Magee, J. and Somogy, C., Progress Reports of Cooperative Research on Wood Ties of the Railway Tie Association and Association of American Railroads Research and Test Department, Association of American Railroads, 1969.
5. Magee, J. and Somogy, C., Progress Reports of Cooperative Research on Wood Ties of the Railway Tie Association and Association of American Railroads Research and Test Department, Association of American Railroads, 1970.

6. Magee, J. and Somogy, C., Progress Reports of Cooperative Research on Wood Ties of the Railway Tie Association and Association of American Railroads Research and Test Department, Association of American Railroads, 1971.
7. Davis, D.D. and Shafarenko, V.M., Tie Condition at Des Plaines, A Progress Report, Report Number WP-131, Association of American Railroads, 1988.
8. Davis, D.D. and Chrismer, S.M., Tie Performance - A Progress Report of the Des Plaines Test Site, Report Number R-746, Association of American Railroads, 1990.
9. Davis, D.D., Tie Condition Inspection - A Case Study of Tie Failure Rate, Modes, and Clustering, Report Number R-714, Association of American Railroads, 1989.
10. Book of Standards, American Wood Preservers' Association, Stevensville, MD, 1989.
11. Lewis, S.L., et. al., Durability of Wood Crossties (Phase I), Report Number R-702, Association of American Railroads, 1987.

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NOTES

The maps on the front and back covers is the first known attempt to make an unbroken map on one sheet of the complete standard gauge railway network of the North American Continent.

While obviously certain details must be omitted on a map of this scale, we would appreciate knowing at AREA Headquarters any corrections or changes you might know about that would improve the map. The intention is to show all standard gauge lines presently in service, and not those under construction or unused and left in place.

**THE
RAILWAY NETWORK
OF THE
NORTH AMERICAN CONTINENT**



**LA RED
FERROVIARIA
DEL CONTINENTE
DE NORTE AMERICA**



